Hyperbolic Discounting, the Sign Effect, and the Body Mass Index

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Hyperbolic discounting, the sign effect, and the body mass index☆

Shinsuke Ikeda[a,*], Myong-Il Kang[b,1], Fumio Ohtake[a,2]

[a] The Institute of Social and Economic Research, Osaka University, 6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan
[b] Department of Business Administration, Korea University, 1-700 Ogawa-cho, Kodaira Tokyo 187-8560, Japan

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ABSTRACT

Analysis of a broad survey of Japanese adults confirms that time discounting relates to body weight, not only via impatience, but also via hyperbolic discounting, proxied by inclination toward procrastination, and the sign effect, where future negative payoffs are discounted at a lower rate than future positive payoffs. Body mass index is positively associated with survey responses indicative of impatience and hyperbolic discounting, and negatively associated with those indicative of the sign effect. A one-unit increase in the degree of procrastination is associated with a 2.81 percentage-point increase in the probability of being obese. Subjects exhibiting the sign effect show a 3.59 percentage-point lower probability of being obese and a 4.02 percentage-point higher probability of being underweight than those without the sign effect. These effects are substantial compared with the prevalence rates of the corresponding body mass status. Obesity and underweight thus result in part from the temporal decision biases.

1. Introduction

This paper examines how interpersonal differences in the body mass index (hereafter, BMI), defined as weight in kilograms divided by height in meters squared (kg/m^2), are related to differences in time discounting, using data from a broad survey of Japanese adults. The focus is on the association of body mass not only with impatience, measured by the level of discount rates, but also with two behavioral properties of time discounting: hyperbolic discounting or the immediacy effect, where a person discounts his immediate future more intensely than his distant future, and the sign effect, where a person discounts positive payoffs more intensely than negative payoffs (e.g., Thaler, 1981; Benzion et al., 1989). To do so, we included questions in the survey that enabled us to measure the respondents' behavioral inclinations in time discounting.

We find that respondents' BMI is associated positively with the degree of impatience and negatively with the sign effect, where the significance levels are higher for the female sample than for the male sample. For example, an increase in impatience by one unit of the standard deviation is associated with an increase in BMI by 1.09% of the BMI mean, a 2.23 percentage-point increase in the probability of being obese, and a 0.83 percentage-point decrease in the probability of being underweight. Subjects exhibiting the sign effect show a 3.69 percentage-point lower probability of being obese and a 4.02 percentage-point higher probability of being underweight than those without the sign effect. These marginal effects are substantial compared with the prevalence rates, i.e., the unconditional probabilities, of the corresponding body mass status (e.g., 18.92% for obesity and 6.92% for underweight).

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* Corresponding author. Tel.: +81 6 6879 8568.
E-mail addresses: ikeda@iser.osaka-u.ac.jp (S. Ikeda), mkang@korea-u.ac.jp (M.-I. Kang), ohtake@iser.osaka-u.ac.jp (F. Ohtake).
[1] Tel.: +81 42 341 1331.
[2] Tel.: +81 6 6879 8572.

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The following is a comment on the published paper shown on the preceding page.

Time Discounting and Body Mass Index: Toward Economics of Obesity and Underweight

IKEDA Shinsuke and OHTAKE Fumio
(Institute of Social and Economic Research)

Introduction and hypotheses

In economic theory, when people make intertemporal decisions, their personal discount rates, which determine as their measure of impatience how much of their resources to consume for present gratification and how much to save for future gratification, are considered to play a key role. Because our body weight is a result of our past intertemporal choices on trade-offs between present gratification from eating and future one from health (and/or beauty), our body mass status (e.g., normal, obese, or underweight) will depend on our time discounting. Although the association between the personal discount rate and body mass status has been discussed in health economics, needed empirical research did not proceed so much.

In this paper, we, jointly with Myong-Il Kang, examined how interpersonal differences in the body mass index (hereafter, BMI), defined as weight in kilograms divided by height in meters squared (kg/m^2), are related to differences in time discounting, using data from a unique broad survey of Japanese adults. The novelty is to focus on the association of body mass not only with impatience, measured by the level of discount rates, but also with two behavioral aspects of time discounting: hyperbolic discounting, where a person discounts his or her immediate future by a higher rate than his or her distant future, and the sign effect, where future losses are discounted at a lower rate than future gains of the same amount. We hypothesize that body weight is associated positively with both impatience and hyperbolic discounting, and negatively with the sign effect.

Data

The research is based on the Japan Household Survey on Consumer Preferences and Satisfaction 2005 (hereinafter, JHS05), a nationwide household survey that the authors conducted in February 2005 as part of the Osaka University COE program, supported by the Ministry of Education, Culture, Sports, and Science and Technology.

Table 1. Summary statistics of the repondents' body mass

		Male	Female
BMI	Means	23.347	21.938
	S.D.	3.119	2.962
Prevalence rates	Underweight (BMI<18.5)	0.042	0.095
	Obesity (BMI≧25)	0.240	0.143
	Severe obesity (BMI≧30)	0.029	0.015
Obs.		1369	1501

We randomly selected 6000 Japanese respondents older than 20 years of age and asked them to fill out questionnaires. Out of the 6000, 2987 responded, where male respondents occupied 47.0%, with the average age of the respondents being 49.08. We included in the survey various questions to elicit information about the respondents' attitudes toward time discounting and risk; their demographic, social, and economic attributes; and their health status including height and weight. From the self-reported data of height and weight, we calculate each respondent's BMI. As summarized in Table 1, the sample mean of BMI is 23.35 for males and 21.94 for females. According to a criterion provided in 2000 by the Japan Society for the Study of Obesity (Examination Committee 2002), the respondents are classified as: underweight if BMI < 18.5; normal if 18.5≦BMI<25; standard if BMI = 22; obese if BMI≧25; and severely obese if BMI≧30. In our data, underweight respondents occupy 4.2% in the male sample and 9.5% in the female sample; obese people occupy 24.0% and 14.3%; and severely obese respondents occupy 2.9% and 1.5%, respectively (see Table 1).

Results

Consistent with our hypotheses, we find that, the respondents' BMI is associated positively with both the degrees of impatience and hyperbolic discounting, and negatively with the sign effect, where the significance levels are higher for the female sample than for the male sample. Figures 1 through 3 summarize the results.

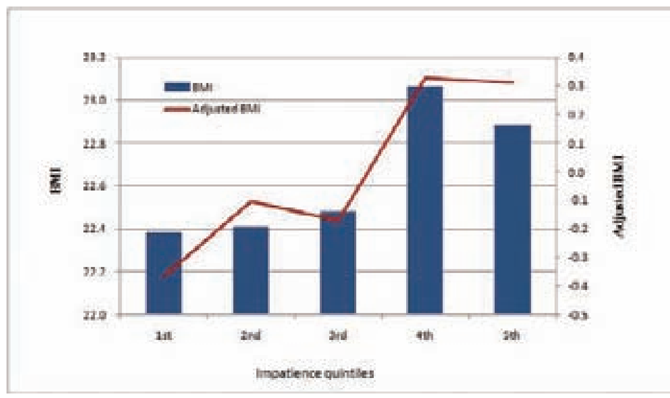

Fig.1 BMI means in impatience quintiles. Note: "1st" represents the most patient quintile. "Adjusted BMI" represents BMI which is adjusted for other personal attributes such as sex, age, income, and the education level. The estimated results are from Ikeda et al. (2010).

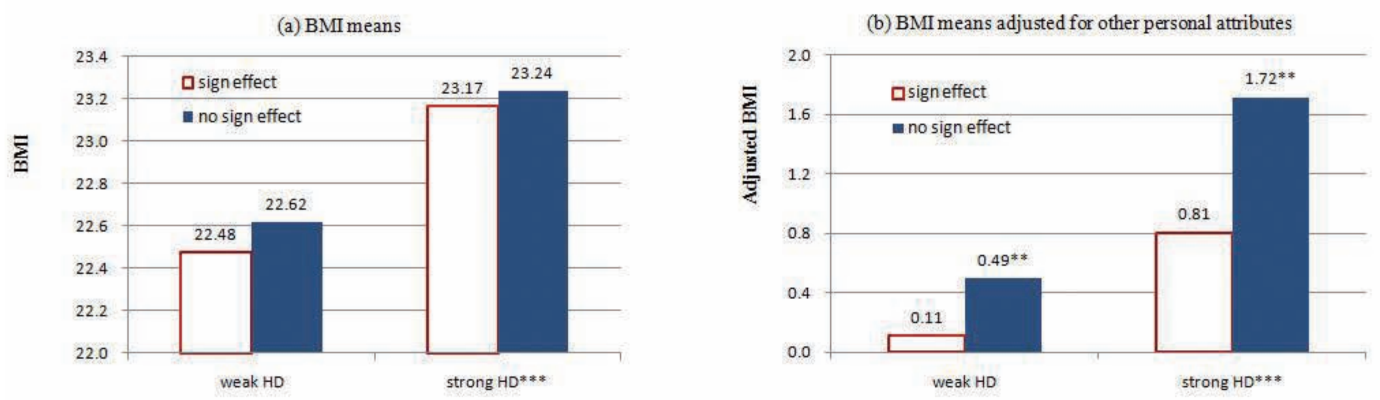

Fig.2 BMI under weak and strong hyperbolic discounting (HD) and with/without the sign effect. *, **, *** Statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure 1 depicts the means of BMI and attribute-adjusted BMI in the quintiles stratified by the degree of impatience. In either case, the BMI means are shown to be positively correlated with impatience.

By sorting the sample by whether predilection toward hyperbolic discounting (HD) is strong or weak, and whether the sign effect is displayed or not, Figures 2(a) and 2(b) compare the BMI means and those means adjusted for other personal attributes. In either figure, BMI is associated positively with the degree of hyperbolic discounting, and negatively with the sign effect.

Based on regressions, Figure 3 estimates the impacts (or marginal effects) of increases in the time discounting variables on BMI and on the probabilities of being obese, severely obese, and underweight. As is shown, a higher degree of impatience is associated with higher probabilities of being obese and of being severely obese, and with a lower probability of being underweight. For example, an increase in impatience by one unit of the standard deviation is associated with an increase in BMI by 1.09% of the BMI mean, a 2.28 percentage-point increase in the probability of being obese, and a 0.83 percentage-point decrease in the probability of being underweight. A one-unit increase in the degree of hyperbolic discounting is associated with a 2.81 percentage-point increase in the probability of being obese and a 0.92 percentage-point decrease in the probability of being underweight. Respondents exhibiting the sign effect show a smaller BMI by 2.17% of the BMI mean, a 1.06 percentage-point smaller probability of being severely obese, and a 4.02 percentage-point higher probability of being underweight than those without the sign effect. These marginal effects are substantial compared with the prevalence rates of the corresponding body status (e.g., 18.92% for obesity and 6.97% for underweight).

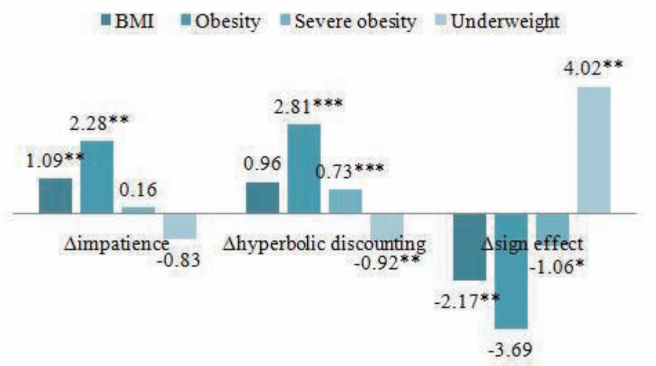

Fig.3 The impacts of an increase in time discounting variables on BMI and the probabilities of being obese, severely obese, and underweight are listed in percentage points. "Δimpatience" represents the impacts of an increase in the discount rate by one unit of sample S.D. of the average discount rate. "Δhyperbolic discounting" shows the impacts of a one-point increase in the degree of procrastination. The row "Δsign effect" summarizes the effect of the presence of the sign effect, compared with the case without the effect. *, **, *** Statistical significance at the 10%, 5%, and 1% levels, respectively. The estimated results are from Tables 9 and 13 of Ikeda et al. (2010).

Conclusions and policy implications

Analysis of an original nationwide survey of Japanese adults confirms that their body weight is expectedly related to their time discounting via impatience, hyperbolic discounting, and the sign effect. The impacts of these preferences on the probabilities of being obese and underweight are not that small, especially compared with the corresponding prevalence rates. Caloric intake and the resultant body mass formation could thus be taken as determined by interetemporal decision-making with behavioral decision bias toward immediacy and/or toward aversion of future losses.

Three policy implications follow. First, policies that raise the immediate costs of caloric intake (e.g., greasy food tax) are likely to be effective at reducing the prevalence of obesity. Second, policies that ease self-control problems (e.g., school education, counteracting advertisements that stimulate consumers' impulsiveness) are also effective. Third, "nudging" policies that change defaults of eaters' choices would also be effective.

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Macroscopic Self-Assembly through Molecular Recognition

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Macroscopic self-assembly through molecular recognition

Akira Harada[1,2]*, Ryosuke Kobayashi[1], Yoshinori Takashima[1], Akihito Hashidzume[1] and Hiroyasu Yamaguchi[1]

Molecular recognition plays an important role in nature, with perhaps the best known example being the complementarity exhibited by pairs of nucleobases in DNA. Studies of self-assembling and self-organizing systems based on molecular recognition are often performed at the molecular level, however, and any macroscopic implications of these processes are usually far removed from the specific molecular interactions. Here, we demonstrate that well-defined molecular-recognition events can be used to direct the assembly of macroscopic objects into larger aggregated structures. Acrylamide-based gels functionalized with either host (cyclodextrin) rings or small hydrocarbon-group guest moieties were synthesized. Pieces of host and guest gels are shown to adhere to one another through the mutual molecular recognition of the cyclodextrins and hydrocarbon groups on their surfaces. By changing the size and shape of the host and guest units, different gels can be selectively assembled and sorted into distinct macroscopic structures that are on the order of millimetres to centimetres in size.

Over the last three decades, a large body of research has been amassed on the topics of molecular recognition[1], supramolecular complexes[2,3] and the self-organization of molecules[4–8]. Recently, much more attention has been directed towards supramolecular polymers[9–12] and materials[13]. Although there have been numerous studies on the self-assembly and self-organization of molecules[14–17] and cells[18,19], there are few that describe macroscopic-scale self-assembly. Self-assembly with macroscopic dimensions has been reported using magnetic interactions[20–22], electrostatic interactions[23,24], hydrophile–lipophile balance[25–28] and capillary effects[29–32]. However, to the best of our knowledge there have been no reports on the self-assembly of macroscopic materials through molecular recognition.

If molecular recognition can be shown to work in a predictable fashion on the macroscopic scale, then macroscopic self-assembly based on molecular recognition should allow a variety of architectures and functions to be realized—and offer new opportunities for materials science[33]. Herein, we demonstrated that macroscopic soft materials, which are on the millimetre or centimetre scale, are differentiated through molecular recognition to give macroscopic association structures. This enables specific molecular recognition events to be visualized on a macroscopic scale. The findings in this study can be applied to instantly connect various soft materials as well as to construct macroscopic architectures using various host and guest combinations, thereby enhancing the concept of supramolecular science as a means to produce practical materials.

Results and discussion

Adhesion of host gels to guest gels. In this study, acrylamide-based gels bearing host (that is, cyclodextrin, CD) or guest moieties were used owing to their relative ease of preparation and the lack of or weak interaction between polyacrylamide and CDs. We selected adamantyl (Ad), *n*-butyl (*n*-Bu) and *t*-butyl (*t*-Bu) groups as the guest moieties (Fig. 1). All the gels were prepared by radical copolymerization under conventional conditions (see Supplementary Information). Additionally, an acrylamide gel bearing neither CD nor a guest moiety (blank gel) was prepared in a similar manner. Most of the gels were stained by dyes for visualization: α-CD-gel (blue), β-CD-gel (red), Ad-gel (light green), *n*-Bu-gel (yellow) and *t*-Bu-gel (dark green).

β-CD-gel was found to bind Ad-gel strongly through molecular recognition. In addition, a mixture of pieces of α-CD-gel, β-CD-gel, *n*-Bu-gel and *t*-Bu-gel exhibited excellent fidelity only by mixing and shaking in water; α-CD-gel specifically adhered to *n*-Bu-gel, and β-CD-gel selectively adhered to *t*-Bu-gel to form macroscopic self-assemblies.

When a piece of β-CD-gel (a host gel) was brought into contact with a piece of Ad-gel (a guest gel) in water, the β-CD-gel adhered firmly to the Ad-gel to form a combined gel (Fig. 2a). When pieces of β-CD-gel and Ad-gel were mixed and shaken in water, β-CD-gel and Ad-gel stuck to each other to form an aggregate (Fig. 2b, Supplementary Movie S2). Closer examination of the aggregate revealed that pieces of β-CD-gel are only in contact with Ad-gel pieces and vice versa (Fig. 2b). In contrast, pairs of β-CD-gel/β-CD-gel or Ad-gel/Ad-gel did not stick together. Moreover in control experiments, pieces of blank gel did not stick together or form aggregates with pieces of β-CD-gel or Ad-gel. These observations indicate that molecular recognition plays an important role not only on the molecular level, but also on the macroscopic level.

The interaction between β-CD-gel and Ad-gel was so strong that it was difficult to separate them from the gel assembly (Fig. 2c). Although the gel assembly did not dissociate at 80 °C, it did above 90 °C, indicative of reversible binding. When the gel assembly was pulled from both sides, one of the gel pieces broke without damaging the contact interfaces. It is noteworthy that the other host gel, α-CD-gel, adhered more weakly to Ad-gel than did β-CD-gel, consistent with the apparent association constants (K_a) estimated using homogeneous aqueous solutions of soluble guest

[1]Department of Macromolecular Science, Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan, [2]Japan Science and Technology Agency (JST), Core Research for Evolutional Science and Technology (CREST), 5 Sanbancho, Chiyoda-ku, Tokyo 102-0075, Japan.
*e-mail: harada@chem.sci.osaka-u.ac.jp