Is body mass human capital in sumo? Outcome of globalization and formation of human capital in Japan

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Eiji Yamamura*

*Corresponding author. Department of Economics, Seinan Gakuin University, 6-2-92 Nishijin, Sawara-ku, Fukuoka 814-8511, Japan.
E-mail address: yamaei@seinan-gu.ac.jp
Tel: +81 92 823 4543; Fax: +81 92 823 2506

ABSTRACT
Sumo wrestling is a traditional fighting sport in Japan and has been popular since the 18th century (the Edo period). Using a data set for all sumo wrestlers in the post-World War II period, this paper investigates how wrestlers' body mass index (BMI) is associated with their win rate and absence rate. Further, the effect of BMI is compared between an early period (before the emergence of foreign wrestlers) and later period (after the emergence of foreign wrestlers). After accounting for endogenous bias using instrumental variables, the key findings are that (1) there is no positive relationship between the BMI and win rate in either the early or later period and (2) there is a positive relationship between the BMI and absence rate in the later period but not in the early period. From the findings in this paper, I make the argument that an increase in the number of immigrants with human capital different from that of domestic labor leads the domestic labor to obtain human capital that does not match its characteristics, thereby reducing the performance of domestic labor.

JEL classification: L83; J24; N35; I15;

Keywords: Sumo wrestling, Body mass index, Human capital, International labor mobility; Immigrant

Running Title: Globalization of sumo

Introduction

Sumo wrestling is a traditional fighting sport in Japan and has been popular since the 18th century. Following World War II, sumo, like other professional sports, such as football (Berlinschi et al., 2013) and baseball (Schmidt and Berri, 2005), has become globalized. In 1968, Takamiyama became the first non-Asian to reach the top division (makuuchi)[1] in sumo. Twenty-five years later, in 1993, Akebono became the first foreign-born yokozuna (the highest rank in the top division). Both Takamiyama and Akebono were born in the United States. Since the retirement of Takanohana in 2003, there has been no domestic Japanese yokozuna. In 2012, 7.5% of sumo wrestlers were officially listed as foreigners, and 33% of wrestlers in the top division were foreigners[2]. Following these drastic changes, sumo has become an international sport in the 21st century.

Differences in the labor quality of sumo wrestlers might be due to technical skill and physical strength. Sumo does not have weight categories, and hence, an increase in body mass might result in higher performance. Hence, the body mass might be considered as human capital in the sumo labor market[3]. Furthermore, foreign wrestlers, especially those born in the United States, have a great advantage in terms of body mass. "Upon their initiation into the sumo world, foreign wrestlers are already equipped with a physique equivalent to that of wrestlers in the top division. They have trained in American football or basketball, and have been excellent players" (Nakajima 2003, 62). In other words, these foreign wrestlers were not obese even though their body mass was extremely high. As a consequence, competitive pressure increased, giving domestic sumo wrestlers a great incentive to increase body mass.[4] On the other hand, extra weight seems to increase injury, which hampers the wrestler's performance.

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1 There are six divisions in sumo: makuuchi (maximum of 42 wrestlers), jūryō (fixed at 28 wrestlers), makushita (fixed at 120 wrestlers), sandanme (fixed at 200 wrestlers), jonidan (approximately 230 wrestlers), and jonokuchi (approximately 80 wrestlers). In total, there are approximately 730 wrestlers attending each tournament. Wrestlers enter sumo in the lowest division, jonokuchi, and ability permitting, work their way up to the top division.

2 In response to the increasing numbers of foreign wrestlers, in 1992, the Japan Sumo Association began regulating the inflow of foreign wrestlers (Nakajima 2003, 120).

3 To put it more precisely, through traditional training, the type of physique required for sumo wrestling can be considered as human capital specific to sumo (Nakajima, 2003, 63–66). However, owing to the limited data and difficulty of measuring physique, this paper uses the body mass index.

4 It was pointed out that there have been rigged sumo matches (Duggan and Levitt 2002). This inevitably impedes fair and open competition. However, most matches have not been rigged, resulting in competitive pressure.

This is the negative effect of body mass. Wrestlers are thought to train to obtain an optimum body mass that trades off these positive and negative effects. However, in 2000, the average body fat ratio was 38.4%, which is far higher than ideal for an athlete (Nakajima 2003, 59)[5]. "The upper weight limit of a Japanese wrestler with consideration of muscular strength was estimated to be 180 kg. That is, it is not appropriate from the viewpoint of exercise that a wrestler's weight exceeds 180 kg" (Nakajima 2003, 60). However, after the emergence of Takamiyama, there have been 18 wrestlers weighing in excess of 180 kg. The inflow of foreign wrestlers has led Japanese wrestlers to misestimate the optimum body mass.

Previous works on sumo (Duggan and Levitt 2002; West 2004) have focused on the norm or the rule shared in the closed sumo world. However, the sumo world has been under the influence of globalization and thus affected by an inflow of foreign-born labor. It is worth investigating the effect of the increasing number of foreign wrestlers on human capital accumulation of domestic wrestlers to explore the impact of immigrants in the labor market. Many works have investigated an individual's physical characteristics (or sporting activities) and their outcomes in the labor market (e.g., Ewing 1998; Barron et al., 2000; Persico et al., 2004: Lechner, 2009; Rooth 2009; 2011; Böckerman et al., 2010). However, these works did not take international labor mobility into account. The sumo world is generally characterized as having been closed to strangers and so was not influenced from the outside until after World War II. That is, Japanese wrestlers are thought to have shared and behaved according to a social norm. On the other hand, the critical influence of international labor mobility has been observed in other professional sports (Schmidt and Berri, 2005; Berlinschi et al., 2013). Naturally, the question arises whether globalization affects the behavior of sumo wrestlers. Analyzing the sumo labor market can be regarded as a natural experiment for examining how inflow of heterogeneous labor affects a closed traditional labor market governed by a social norm.

To explore the question, using the tournament records of sumo wrestlers in the post-World War II period (1945–2013), during which there was a drastic change in the sumo labor market, this paper considers how the body mass index (BMI) is associated with the win rate and absence rate of sumo wrestlers. It also compares the relationships before and after the emergence of foreign wrestlers.

The paper is organized as follows. Section 2 explains the data set and simple econometric framework. The results of the estimations and a discussion are provided in

[5] The ideal body fat ratio is 10% and 13% for a soccer player and American football player, respectively.

Section 3. The final section offers concluding observations.

Data and methods

In this paper, I use the win rate and absence rate to capture the performance of wrestlers. An increase in body mass is expected to improve wrestlers' performance because a wrestler with a better physique will have an advantage. The degree of fatness cannot appropriately be captured by an individual's weight. This is because the taller someone is, the heavier they will be for the same degree of fatness. The BMI is calculated from a person's weight and height, and is a reliable indicator of body fatness for adults[6]. In the field of economics, the BMI is generally used to capture the degree of fatness (e.g., Zellner et al., 2004; 2007; Chrzanowska et al, 2007; Vignerova et al., 2007; Saint Onge et al., 2008; Yamamura 2012). Although a higher BMI can benefit a sumo wrestler, it also increases the probability of injury, thus lowering performance. Hence, it is an empirical question whether body mass is positively associated with a wrestler's performance. This paper addresses this question.

2.1. Data

There are six Grand Sumo Tournaments (basho) each year. In each tournament, there are 15 bouts. This paper mainly uses wrestlers' tournament-level data[7]. Table 1 presents construction of the data used for this paper. Data 1 consists of tournament records of the top division for each wrestler. Within the top division, there are roughly five ranks: *Yokozuna* (the highest rank), *Ozaki* (the second rank), *Sekiwake* (the third rank), *Komusubi* (the fourth rank) and *Maegashira* (the fifth rank). To put it more

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6 BMI = weight (kg) / (height (m))^2. The BMI is not necessarily a suitable proxy variable for obesity in the sumo world because the average body fat ratio of sumo wrestlers in the top division is around 20–25%. Gaining weight does not always mean obesity. What is more important is the balance between the upper and the lower half of the body. However, data on this balance are not available and so cannot be used for statistical analysis. Careful attention should therefore be paid when estimations using BMI (and weight) are interpreted.

7 Panel data from individual wrestling matches are used in literature to empirically analyze sumo (Duggan and Levitt 2002; Hori and Iwamoto 2013). These works mainly examine the probability of winning a particular bout, in an attempt to scrutinize the possibility of rigging it. For that purpose, this match-level panel data is valuable. However, this paper aims to examine the impact of foreign wrestlers not only on the win rate but also on the absence rate. The panel data from wrestling matches cannot be used to analyze absence rates. Further, in sumo tournaments, wrestlers compete against others of similar rank. Tournament level data can therefore capture the ranking of wrestlers in each tournament and so control for strength of opponent to some extent. I have therefore used tournament-level panel data rather than match-level in this paper.

precisely, within *Maegashira,* each wrestler is ranked from the top to the bottom. In each tournament, there are usually 42 wrestlers in the top division. Among them, the number of Maegashira wrestlers is about 30. There are far more Japanese Maegashira (9,894) than there are Japanese wrestlers of higher rank. This indicates that it is difficult for wrestlers to advance to a higher rank. The sample of foreign wrestlers shows quite a different pattern. Here, the number of *Yokozuna* is about two and half times more than *Maegashira*. In this sample, the higher the rank, the larger the sample size becomes. Therefore, foreign wrestlers are thought to advance rapidly to higher ranks and then play bouts mainly as *Yokozuna* or *Ozeki*. This implies that foreign wrestlers' performance is distinctly higher than that of Japanese wrestlers.

All wrestlers start in the lower divisions and then advance to higher divisions. During this process, weight and BMI are thought to increase through training to improve physique. However, unfortunately, height and weight in the lower division cannot be obtained for most wrestlers, especially for the period before foreign wrestlers emerged. It is therefore difficult to precisely examine changes in physique over the long term. In this paper, it is assumed that the physique of wrestlers does not change after they advance to the top division. The height and weight at which each wrestler obtained his best results is used and is considered to be constant for each wrestler while he is in the top division. However, actual weight and BMI can vary between tournaments, even for the same wrestler. Values of height and weight can only rarely be obtained, but are available for a portion of wrestlers. Even if there is some estimation bias, the panel data covering moves from the lower to higher divisions is useful to control for a wrestler's individual level characteristics, even for those who were not measured. During the post-war period in Japan, Japanese people generally improved their physique. Therefore, there is a difference of weight and BMI between generations. The panel data therefore enable us to control a wrestler's cohort effect and so disentangle the effect of foreign wrestlers' emergence from the general Japanese physical improvement. Data 2 is the panel dataset. Compared with Data 1, it reveals that the number of Japanese wrestlers in the top divisions apparently decreased. However, Data 2 includes 2307 observations of lower divisions and so is valuable in considering changes of weight and BMI for the same wrestlers.

The data comprise the age, number of wins, number of losses and number of absences in each tournament. If a wrestler is injured and cannot fight, he can be absent from the tournament[8]. From these data, the win rate and absence rate are calculated, which vary

[8] There are various causes of absence. If a wrestler is injured before a tournament, he will be absent from 15 bouts. If he is injured after several bouts of the tournament, he

by tournament. Information about each wrestler's individual characteristics includes birth place, nationality, height and weight. Using height and weight, BMI were calculated.

From information provided by an editorial on sumo (Grand Sumo Encyclopedia, 2001), Mizuno and Kyosu (2011), and the official website of sumo[9], this paper constructs the tournament records of 479 sumo wrestlers. Because of limited data availability, the data were only for those wrestlers who advanced to the top division during the period 1945–2013, even though there were six divisions during this period. The emergence of the first foreign-born wrestler in 1968 is regarded as a turning point. Accordingly, the tournament data are classified into the 'early' period, 1945–1967 and the 'later' period 1968–2013.

Figure 1 illustrates the changes in the total number of foreign wrestlers across all divisions in sumo. The figure shows that the number of foreign wrestlers has dramatically increased since 1970. Figures 2, 3 and 4 show the distributions of the BMI, win rate and absence rate, respectively. The BMI is almost normally distributed except for outliers beyond 60. The win rate is also almost normally distributed. Figure 4 reveals that most wrestlers have never been absent from a bout. Figure 5 shows the relationship between the BMI and year of birth. The Hawaii-born Konishiki, whose BMI exceeded 80, had a distinctly large body mass. Musashimaru, who was also born in Hawaii, had the second-highest BMI of approximately 65. A cursory examination of Figure 5 shows that the BMI is positively associated with the year of birth, which is consistent with the improvement of physique in Japan (Yamamura 2012). However, it is not clear that the increasing size of sumo wrestlers is a result of the inflow of foreign wrestlers, because the average BMI seems to be increasing not only for sumo wrestlers but also Japanese people in general. In the subsequent sections, regression estimations are conducted to closely examine whether the inflow of foreign wrestlers has increased Japanese wrestlers' weight and BMI. Figure 6 suggests a positive association between the BMI and win rate, which is in line with the inference that body mass can be regarded as human capital in sumo. Figure 7 suggests there is no relationship between the BMI and absence rate.

Table 2 compares mean values of various aspects of wrestler records between the two periods (i.e., 1945–1967 and 1968–2013). In Table 2, apart from for absence rate, the differences between periods are statistically significant. In the later period, weight was about 25 kg heavier than that in the early period, and height about 5 cm more. The

will be absent from the remaining bouts.

9 http://sumodb.sumogames.de/Default.aspx

table also shows that the BMI in the later period was 5.7 points higher than in the early period, which is in line with other professional sports (Saint Onge et al., 2008).

Table 3 compares mean values between domestic Japanese wrestlers and foreign wrestlers. Again except for absence rate, differences between the two are statistically significant. Table 3 shows that the win rate of foreign wrestlers was higher than that of domestic wrestlers. The average weight of foreign wrestlers was 37 kg more, while their average height was 8cm more. The average BMI of foreign wrestlers was 6.8 points higher. These findings jointly suggest that the foreign wrestlers' higher BMI increases their win rate, and potentially, although the difference was not statistically significant, may contribute to higher absence rates. Hence, not only the quantitative increase in foreign wrestlers, but also their qualitative superiority, is thought to have affected domestic wrestlers.

2.2. Econometric framework to examine wrestlers' physique.

Before examining the effect of BMI and weight on the win rate and absence rate, it is necessary to test the assumption that the inflow of foreign wrestlers increases the Japanese wrestlers' BMI and weight. To this end, Data 2, presented in Table 1, was used for estimations. Foreign wrestlers were excluded from this sample because this paper aims to analyze the effect of foreign wrestlers on Japanese wrestlers[10]. The form of the estimated function is:

$BMI\ (\text{or } Weight)_{it} = \alpha_0 + \alpha_1 International\ period\ dummy_t + \alpha_2 Injury\ system\ dummy_t + \alpha_3 Komusubi\ dummy_{it} + \alpha_4 Sekiwake\ dummy_{it} + \alpha_5 Ozeki\ dummy_{it} + \alpha_6 Yokozuna\ dummy_{it} + \alpha_7 Age_{it} + k_i + u_{it}$,

where BMI (or $Weight$)$_{it}$ represents the dependent variable for individual i and for tournament t. When *Weight* is the dependent variable, *Height* is added as an independent variable. The regression parameters are denoted α and the error term is u_{it}. Since the panel data is used, a wrestler whose individual characteristics were unmeasured can be captured by k_i. As explained earlier in subsection 2.1, Japanese people generally improved their physique after World War II. Therefore, BMI and weight of Japanese people generally seems to increase with later year of birth. The birth year of each wrestler is fixed and so the generation effect can be controlled by k_i. *International period dummy* takes 1 after the emergence of foreign wrestlers, that is, during or after 1968, and 0 before or during 1967. If the inflow of foreign wrestlers

10 However, the estimation results based on a sample including foreign wrestlers do not change from those reported in this paper. These results are available upon request from the author.

increased Japanese wrestlers' BMI and weight, the sign of coefficient of *International period dummy* will be positive.

In the sumo world, an absence from an official match is traditionally treated as a loss. However, in this case, the wrestlers' incentive to exert all their energy in a match is reduced, because a match played in earnest inevitably increases the probability of injury. Consequently, wrestlers may fail to put in all possible effort in any given match, to avoid getting injured. In order to reduce the risk of the match not being fought in earnest, the injury-on-duty system was adopted in 1972 (Nakajima 2003). Under this system, wrestlers who were injured in an official match and defaulted in the next tournament were not treated as absent. However, as a result of adopting the system, the number of absences increased, and it became difficult to set an exciting match. In order to improve the situation, the injury-on-duty system was altered in 2004, so that an injury that may have been caused by the wrestler being overweight is unlikely to reduce their rank and income level. Coupled with the fact that evidence seemed to suggest to Japanese wrestlers that it was important to increase in BMI and weight in order to compete effectively with foreign wrestlers, the system is thus inferred to increase Japanese wrestlers' weight and therefore BMI. In order to capture this effect, the function incorporates *Injury system dummy*, which takes 1 during the period 1972–2003, and otherwise 0. Its coefficient is predicted to be positive.

In addition, dummies for wrestlers' rank are included: *Komusubi dummy, Sekiwake dummy, Ozeki dummy* and *Yokozuna dummy.* On the assumption that wrestlers with higher performance tend to have higher BMI and weight, then the higher wrestlers' BMI and weight, the higher the rank of the wrestlers. If this is true, these dummies will be positive. Further, the higher the rank, the larger the value of their coefficient. In addition, *Age* is incorporated to capture experience. Training in sumo is thought to improve the physique of wrestlers. The greater the experience, the higher the BMI and weight, so the coefficient of *Age* is predicted to be positive.

2.3. Econometric framework to examine wrestler's win rate and absence rate.

After testing the assumptions, as the main estimation, I attempted to assess the effects of body mass on the win rate and absence rate. Following the description above, the estimated function takes the form

$$\textit{Win rate } (\text{or } \textit{Absence rate})_{it} = b_0 + b_1 BMI_i + b_2 \textit{Injury system dummy}_t + b_3 \textit{Komusubi dummy}_{it} + b_4 \textit{Sekiwake dummy}_{it} + b_5 \textit{Ozeki dummy}_{it} + b_6 \textit{Yokozuna dummy}_{it} + b_7 Age_{it} + e_{it},$$

where *Win rate (*or *Absence rate)*$_{it}$ represents the dependent variable. The regression parameters are denoted α and the error term e. *Win rate (*or *Absence rate)* ranges between 0 and 100. Hence, a Tobit model is appropriate for the estimation. The key independent variable is the BMI, denoted *BMI.* In an alternative specification, *Weight* and *Height* are incorporated instead of *BMI* to separate out the BMI into its constituent parts[11]. BMI and weight cannot be obtained because of the scarcity of data. Therefore, as explained in the previous section, on the assumption that wrestlers' physique is almost stable in the top division, the value of BMI into weight in each wrestler's period of greatest success is used. If a better physique improves performance, *BMI* (and *Weight*) is expected to be positive when *Win rate* is the dependent variable. On the other hand, if being overweight increases the chance of the wrestler getting injured and then being absent, *BMI* (and *Weight*) will be positive when *Absence rate* is the dependent variable. For the purposes of comparing the periods before and after the advent of foreign wrestlers, the sample in Data 1 was separated into these two periods and estimations were conducted in each sample[12].

As explained previously, under the injury-on-duty system, wrestlers' BMI and weight tend to be higher. If this is true, the system increases the probability of getting injured. Therefore, *Injury system dummy* is predicted to be positive when *Absence rate* is the dependent variable.

Higher-ranked wrestlers are predicted to have a higher win rate. Hence, the wrestlers' rank dummy will be positive when *Win rate* is the dependent variable. The higher the rank, the larger the value of their coefficient. A sumo wrestler's eighth loss in a tournament means a majority of losses because there are 15 matches in each tournament. In this case, apart from Yokozuna and Ozeki, wrestlers will move to the next rank down for the next tournament. If an Ozeki suffer more losses than wins for a series of two tournaments, he will automatically be demoted. However, this is not the case for Yokozuna[13]. Thanks to such privilege, Yokozuna are less likely to avoid absence than Ozeki. All in all, *Ozeki dummy* and *Yokozuna dummy* are expected to be

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11 Relation between the BMI (or weight) and wrestler's performance is not considered as linear because there seems to be an optimal level of BMI (or weight). The assumption of this paper is as follows: before the advent of foreign wrestlers, BMI (or weight) did not reach the optimal level. After this point, BMI (or weight) was beyond the optimal level. The sample is divided into two periods and so the linear relationship between them is assumed to be valid.

12 The sample used in this paper does not include foreign wrestlers. The estimation results based on a sample which included foreign wrestlers do not change from those reported in this paper. These results are available upon request from the author.

13 That is to say, the performance of a Yokozuna does not influence his rank at all. Therefore, ordinarily, a majority of losses for a Yokozuna will cause him to retire.

positive when *Absence rate* is the dependent variable. Further, the value of the *Yokozuna dummy* is predicted to be much larger than the *Ozeki dummy*.
Experience in sumo improves the technique and so increases win rate. Wrestlers' age thus increases their win rate. However, the older the wrestler, the lower his physical condition; hence, age may also reduce the win rate. It is therefore an empirical question as to whether age increases or decreases win rate. Age is expected to increase absence rate owing to the decline in physical condition. The predicted sign of *Age* is therefore positive when the dependent variable is *Absence rate.*

2.3. Instrumental variables

There is possibly reverse causality in the relation between the BMI and the dependent variables *Win rate* and *Absence rate*. The lower the win rate, the more the wrestler has an incentive to increase body mass to improve his performance. On the other hand, the higher the absence rate, the more the wrestler has an incentive to decrease his body mass to reduce the possibility that he is injured. Hence, endogenous bias inevitably occurs. It is thus necessary to control for this.
To control for the bias, the instrumental-variable Tobit method (IV Tobit) is used in alternative estimations of *Win rate* and *Absence rate*, respectively. Outside the sumo world, it has generally been observed that the Japanese physique has improved in tandem with economic development (Yamamura, 2012). Therefore, the birth year of wrestlers is positively associated with *BMI* whereas it is related to neither *Win rate* nor *Absence rate.* Accordingly, *Birth year* is included in the set of instrumental variables.

In addition, the degree of urbanization in the area of a wrestler's residence seems to be related to lifestyle and calorie intake. Lifestyle during childhood affects body mass, which is possibly maintained into adulthood. The place where a wrestler grows up is thus related to the wrestler's BMI. On the other hand, I assume that childhood circumstances are not directly associated with *Win rate* or *Absence rate.* Generally, the Kanto area, including Tokyo, Kanagawa, Saitama, and Chiba, is considered an urban area in eastern Japan, while the Kansai area, including Osaka, Hyogo, and Kyoto, is considered an urban area in western Japan. *Kanto dummy* and *Kansai dummy* thus provide information about the birthplace of wrestlers. To capture the long-run effect of birthplace, *Kanto dummy* and *Kansai dummy* are added to the set of instrumental variables.

Estimation results and their interpretation

3.1. Results based on Data 2.

Table 4 reports results for *BMI* and *Weight,* estimated by the Fixed effects model. Table 5 presents results for *Win rate*, while Table 6 exhibits results for *Absence rate.* The results of Tables 5 and 6 are estimated by the Random Tobit model. In each table, columns (1) and (3) show results based on the full sample, while columns (2) and (4) show results based on the sample excluding foreign wrestlers. In Tables 5 and 6, columns (1) and (2) give the results of the estimation when the BMI is incorporated, and columns (3) and (4) give them when weight and height are included instead of the BMI.

In Table 4, the coefficient of *International period dummy* is positive and is statistically significant in all estimations. This indicates that the advent of foreign wrestlers increased wrestlers' BMI and weight, even after controlling for various effects such as generation, the injury-on-duty system, rank, and age. The value of the coefficient is 1.18 in column (2), meaning that the advent of foreign wrestlers increased Japanese wrestlers' BMI by 1.18 points on average. The value of the coefficient is 2.39 in columns (4), meaning that the advent of foreign wrestlers increased Japanese wrestlers' weight by 2.39 kg. *Injury system dummy* is positive and statistically significance in all estimations. This suggests that, consistent with my prediction, the injury-on-duty system gives wrestlers an incentive to increase BMI and weight. The value of the coefficient of *Injury system dummy* is 0.92 in column (2) and 1.78 in column (4). Hence, wrestlers increased their BMI by 0.92 points and their weight by 1.78 kg under the injury-on-duty system. This shows that the effect of foreign wrestlers is larger than that of the system.

All the rank dummies are positive and are statistically significant at the 1% level, shown in columns (1)–(4). The absolute values of *Komusubi dummy*, *Sekiwake dummy,* and *Ozeki dummy* are around 2 in column (2), and around 6 in (4). Hence, compared with lower classes and divisions, wrestlers in these classes have a BMI that is two points higher and a weight 6 kg higher. The values of the Yokozuna dummy are 2.92 in column (2) and 9.97 in column (4), which implies that Yokozuna wrestlers have distinctly higher BMI and weight than others. This could be interpreted in two ways. First, the overwhelming strength of the Yokozuna wrestler can by explained in part by the degree of human capital captured by BMI and weight. Second, absence does not cause a Yokozuna wrestler to be demoted. Hence, their BMI and weight become far higher than the optimal level. The coefficient of *Age* is positive and statistically significant at the 1% level in columns (1)–(4). Values of age are 0.66 in column (2) and 2.00 in column (4), which implies that additional age leads to a 0.66 point increase in BMI and 2 kg in weight. This can be interpreted as human capital, as captured by physique, increasing through training and greater experience of sumo.

In Table 5, *BMI* and *Weight* are negative in columns (1)–(4). However, they are not statistically significant, which indicates that *BMI* and *Weight* do not influence win rate. The significant positive nature of the *Ozeki dummy* and *Yokozuna dummy* is in line with the prediction.

Table 6 suggests that *BMI* and *Weight* are positive and statistically significant in columns (1)–(4), meaning that they increase absence rate. This suggests that having a BMI and weight which are higher than the optimal level increases the probability of getting injured. *Injury system dummy* is positive and statistically significant in all columns. In line with the prediction, the injury-on-duty system made wrestlers more likely to be absent from tournaments because they were not demoted to lower classes as a result. Both *Ozeki dummy* and *Yokozuna dummy* are positive. It is also interesting to observe in column (2) that the value of *Yokozuna dummy*, 186.7, is about three times larger than the value of *Ozeki dummy*, 63.6. A similar result is exhibited in other columns. This might be because there is no probability of a Yokozuna being demoted to a lower rank. Considering Tables 5 and 6 together leads me to note that the effect of the Yokozuna rank on absence rate, which is three times larger than the effect of the Ozeki rank, is relatively larger than the effect on win rate, which is only one and half times larger than the Ozeki rank effect.

Estimations of win rate and absence rate reported in Tables 6 and 7 are based on the sample covering only a portion of the wrestlers who appeared in the top division. In the following subsection, I will therefore look at the results based on the sample containing the tournament records all the wrestlers in the top division.

3.2. Results based on Data 1.

Tables 7–10 present results based on the tournament records of the top division, excluding foreign wrestlers[14]. Results using the Tobit model are reported in Tables 7 and 8, while those using the IV Tobit model are in Tables 9 and 10. Results of win rate are shown in Tables 7 and 9, and those of absence rate in Tables 8 and 10. In each table, the sample is divided into the close period (1945–1967) and international period (1968–2013), and estimations are then conducted. In the studied period, there were eight wrestlers whose weight was over 200 kg. Half of them were Japanese wrestlers, and the rest were born in the United States[15]. However, after 2003, there were no

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14 The results based on data including foreign wrestlers are available upon request from the author.

15 All of them were Hawaii-born, such as Takamiyama, Konishiki, Akebono and Musashiamru.

wrestlers born in the United States. Instead, wrestlers born in Mongolia become a majority of foreign wrestlers. Generally, Mongolian wrestlers' average BMI and weight is almost equivalent to that of Japanese wrestlers. Therefore, the effect of the advent of foreign wrestlers on physique seems to decrease after 2003. To control for this, an alternative international period sample covers from 1968 to 2003. Results based on the full sample are reported in columns (1) and (5). The results based on the closed period sample are reported in columns (2) and (6), and those based on the international sample are reported in columns (3), (4), (7) and (8).

From columns (1) and (5) of Table 7, it is clear that *BMI* and *Weight* are positive but not statistically significant based on the full sample. In the closed period, as shown in columns (2) and (6), *BMI* and *Weight* are positive and statistically significant at the 1% level. On the other hand, in the international period, with the exception of column (3), *BMI* and *Weight* are negative. However, they do not show statistical significance in columns (3), (4), (7) and (8). This implies that high *BMI* and *Weight* led to improvements in performance before the advent of foreign wrestlers. However, this positive effect disappeared after the advent of foreign wrestlers. The results of the control variables are similar to those in Table 5.

Table 8 shows that *BMI* and *Weight* are positive and statistically significant at the 1% level based on the full sample. In the closed period, *BMI* and *Weight* are negative and not statistically significant. Then, in the international period, they are positive and statistically significant at the 1% level in columns (3), (4), (7), and (8). These show that an increase in weight and BMI did not affect the probability of getting injured before the advent of foreign wrestlers. However, weight and BMI exceeded the optimal level after this point, resulting in an increased probability of injury. The results for the control variables are almost the same as in Table 6.

To examine the effect of physique by controlling for its endogeneity bias, I now turn to the results obtained with the IV Tobit, in Tables 9 and 10. An over-identification test can examine the exogeneity of instrumental variables. Test statistics are not significant in columns (1) and (5) and thus do not reject the null hypothesis that the instrumental variables are uncorrelated with the error term. Hence, the IV Tobit method can be considered valid in columns (1) and (5). Care is needed, however, when the other results are interpreted. The results of the control variables are almost the same as those in Tables 7 and 8, and so here, interpretation of results is limited to key variables *BMI* and *Weight.* Based on the full sample, in columns (1) and (5), *BMI* and *Weight* is negative and statistically significant at the 1% level. What is more, the absolute value of *BMI* is 0.15, meaning that a one-point increase in BMI results in a decrease of

0.15% in the win rate. The absolute value of *Weight* is 0.05, meaning that a 1 kg increase in weight leads to a decrease of 0.05% in the win rate. It is surprising to observe that *BMI* and *Weight* become negative even though they are not statistically significant in the closed period. Combining the results shown in columns (2) and (6) of Table7 and those of Table 9 implies that the positive effect of physique disappears after controlling for endogeneity even in the closed period. In the international period, *BMI* and *Weight* are negative, and they are statistically significant in columns (4) and (6).

Turning to Table 10, over-identification test statistics are not significant in most cases, with the exception of columns (3) and (7), and thus do not reject the null hypothesis that the instrumental variables are uncorrelated with the error term. Hence, the IV Tobit method can be considered valid. Based on the full sample, in columns (1) and (5), the coefficient of *BMI* and *Weight* is positive and statistically significant at the 1% level. It is interesting to observe that the coefficient of *BMI* and *Weight* is negative and statistically significant in columns (2) and (6). The absolute value of *BMI* is 5.16, implying that the absence rate declines by 5.16 % when the BMI increases by one point. The absolute value of *Weight* is 1.59, implying that the absence rate declines by 1.59% when weight increases by 1 kg. Wrestlers are inclined to withdraw from a tournament because of serious injury. Therefore, an increase in *BMI* and Weight can be considered to improve physical strength and prevent injury or reduce its extent, thus reducing the absence rate. However, as shown in columns (3), (4), (7) and (8), *BMI* and *Weight* continued to be positive and statistically significant at the 1% level. In column (4), the absolute value of *BMI* is 12.6, implying that the absence rate rises by 12.6 % when the BMI increases by one point. In column (8), the absolute value of *Weight* is 3.67, implying that the absence rate rises by 3.67% when weight increases by 1 kg. This can be interpreted as implying that obesity resulted in wrestlers being injured in bouts, thus increasing the absence rate. In summary, an increase in *BMI* (or *Weight*) may reduce the probability of injury to a certain optimum level, but after that, increases it.

Overall, contrary to expectation, the body mass is not associated with the win rate, but has a critical influence on the absence rate, although whether the influence is positive or negative depends on the situation. The combined results of Tables 4–10 suggest that the inflow of foreign wrestlers has led to domestic Japanese wrestlers becoming obese, which eliminates the positive effect of body mass on their performance. In comparison with Westerners, Japanese people are generally shorter and have a disadvantage relating to physique. However, they have a comparative advantage in terms of technique and agility. Hence, to compete with foreign wrestlers, Japanese wrestlers should train to improve technique or improve agility, rather than increase body mass. However, they have not adopted such a strategy. Therefore, the arrival of immigrants with a different type of human capital has enhanced accumulation of human capital that is not suitable to domestic wrestlers. Arguments about the impact of immigration vary and so are inconclusive. Some works provided evidence that highly-skilled immigrants increased innovative activities and generated beneficial spillover in the domestic economy (e.g., Vidal 1998; Stark and Wang 2002; Chellaraj et al., 2008). Others suggested that immigration increased the wage level of native workers (Ottaviano and Peri 2012). However, the effect of immigration may depend on the skill characteristics of the native and immigrant workers (Peri and Sparber 2009, Borjas et al., 2008). In the sumo labor market, foreign wrestlers with low skill do not improve the skills of domestic wrestlers. Instead, the better physique of foreign wrestlers triggered domestic wrestlers' "innovative activities" to increase weight, generating spillover. However, such spillover is detrimental to the performance of domestic wrestlers. That is, in the case of sumo, foreign wrestlers are considered as a substitute for domestic workers, leading the sumo labor market to be competitive. In addition, the arrival of foreign wrestlers lowered the performance of domestic wrestlers through the effects of "innovative activities" and negative spillover.

Conclusion

Since the 1970s, an increasing number of foreigners have entered the sumo labor market, leading sumo to become an international sport. In particular, wrestlers born in the United States have a great advantage in terms of physique over domestic Japanese wrestlers. In such a drastically-changing environment, to counter the inflow of foreign wrestlers, domestic Japanese wrestlers have accumulated human capital by increasing their body mass.

The increase in body mass is expected to improve wrestlers' performance. On the other hand, it increases the probability of injury, thus lowering performance. Hence, it is an empirical question as to whether the body mass is positively associated with a wrestler's performance. This paper used a dataset of tournament records for each wrestler to investigate the effect of wrestlers' BMI on their win rate and absence rate. The key findings are that 1) an increase in BMI did not result in a higher win rate in either the closed period (before the arrival of foreign wrestlers) or the international period (after their arrival) and 2) an increase in BMI raised the absence rate in the international period but reduced it in the closed period.

In my interpretation, before the arrival of foreign-born wrestlers, an increase in body mass reflected the strengthening of a wrestler's physique. This reduced the probability of injury, although it did not increase the win rate. After the arrival of foreign wrestlers, overweight wrestlers became more inclined to suffer injury and did not have improved win rates. Considering these findings jointly leads me to argue that an increase in body mass improved performance prior to globalization. However, the competition from foreign wrestlers led domestic wrestlers to become overweight, which hampered their performance. The performance of wrestlers depends not only on body mass but also on technique and agility. In comparison with Westerners, Japanese people are generally shorter and more lightweight, suggesting that Japanese wrestlers have a comparative advantage in terms of technique and agility. Hence, the best strategy for Japanese domestic wrestlers would be to improve technique and agility rather than increase body mass. Traditional training encourages Japanese sumo wrestlers to maintain an optimum body mass and maximize their performance by improving their agility and technique matched to their physique. Sumo society is known to have been governed by the traditional social norm, and Japanese wrestlers are therefore thought to put a high value on traditions, including the way of training. However, contrary to tradition, the findings of this study make it clear that the arrival of foreign wrestlers with better physiques misled domestic wrestlers into gaining weight above their optimum level. There seems to be the possibility of multiple equilibria in the labor market. As a consequence of the arrival of heterogeneous foreign wrestlers, the equilibrium of the traditional sumo world became the equilibrium of the globalized sumo world.

From the findings in this paper, I make the argument that an increase in immigrants with human capital different from that of domestic labor leads the domestic labor to obtain human capital that does not match their characteristics, thereby reducing their performance. There is, however, another possibility, observed in professional football, that learning from players with advanced human capital such as excellent skill or physique improves the performance of players in less-developed countries (Yamamura, 2009; Berlinschi et al., 2013). Hence, it is important to consider which type of human capital matches the characteristics of domestic labor when we analyze the learning effect of foreign labor in less-developed countries.

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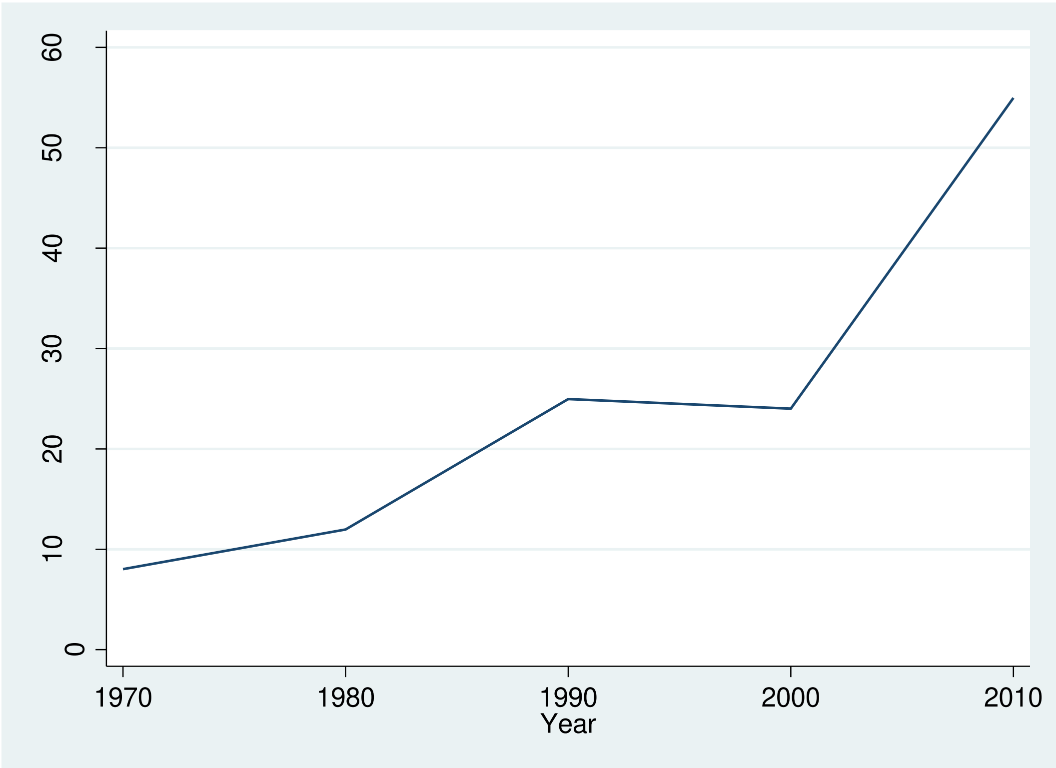
Figure 1. Number of foreign-born wrestlers



Source: SUMO reference (http://sumodb.sumogames.com/Default.aspx?l=e).

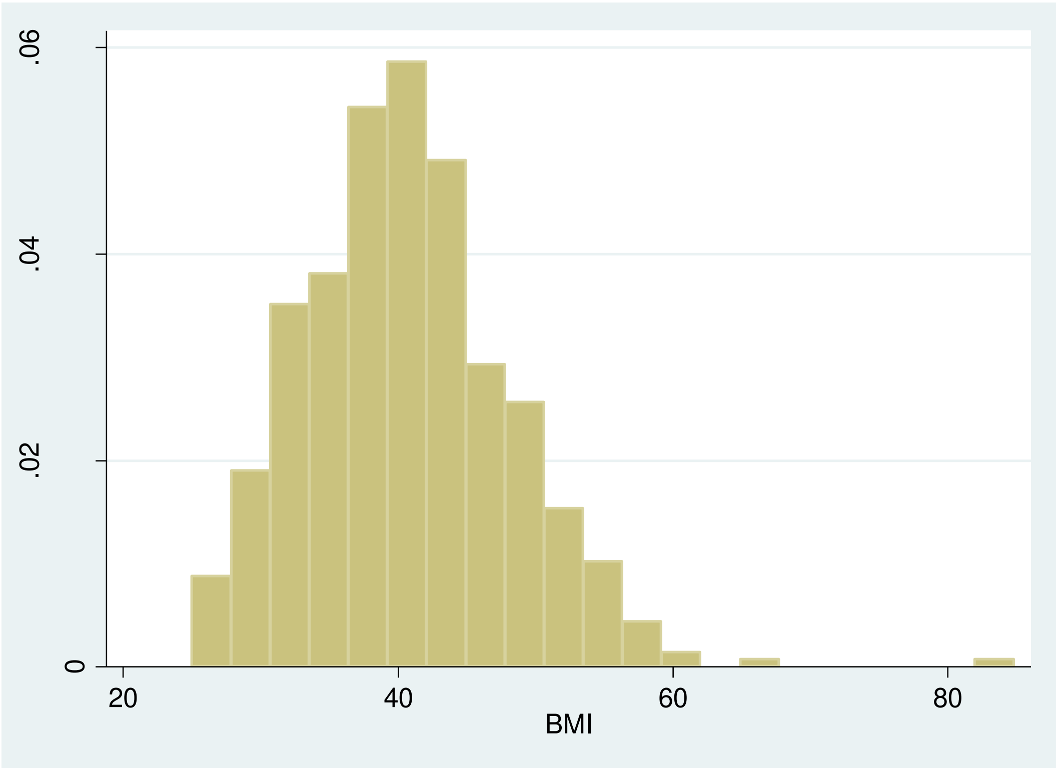


Figure 2. Distribution of BMI

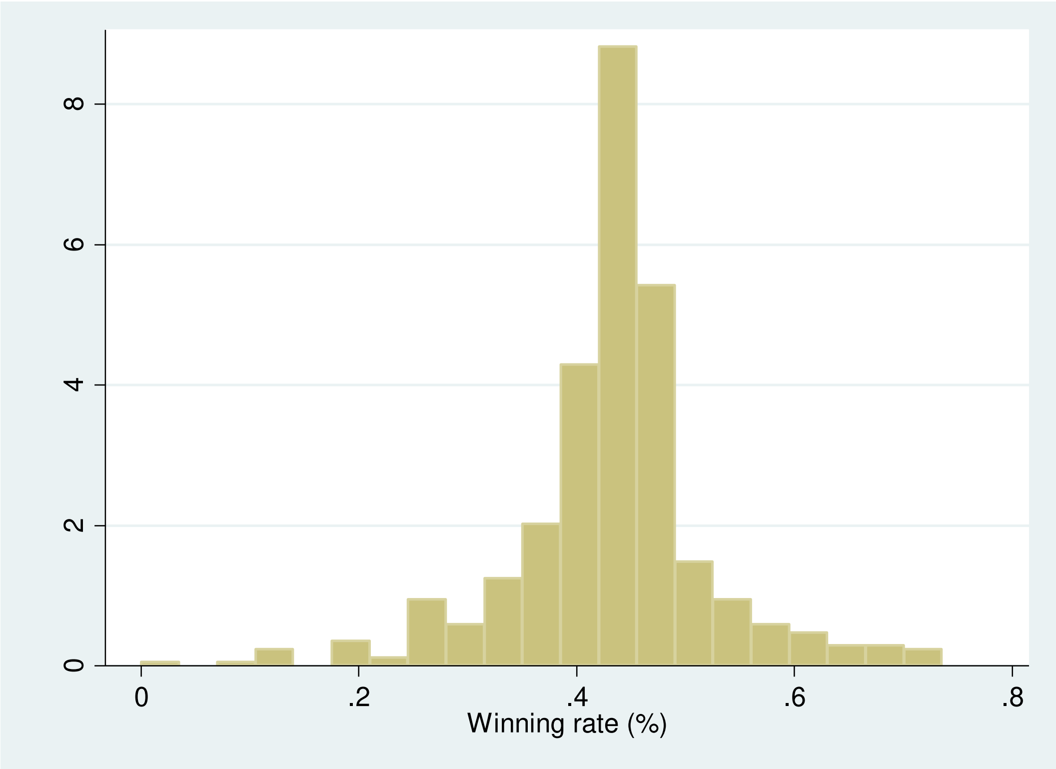


Figure 3. Distribution of win rate

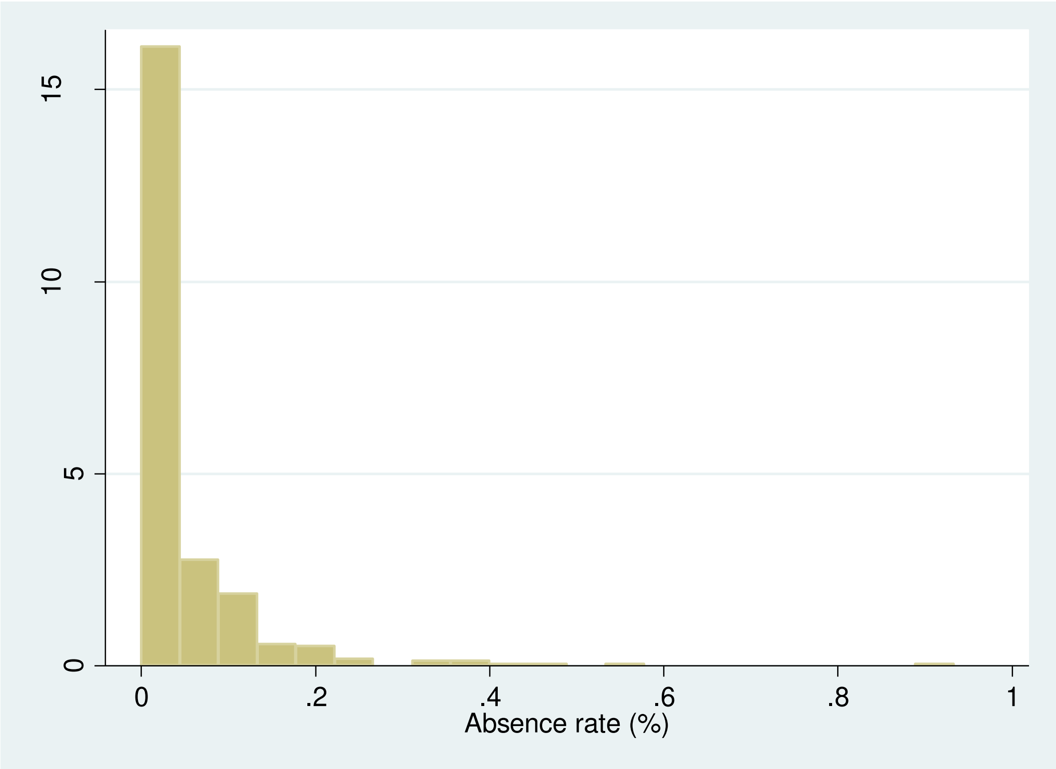


Figure 4. Distribution of absence rate

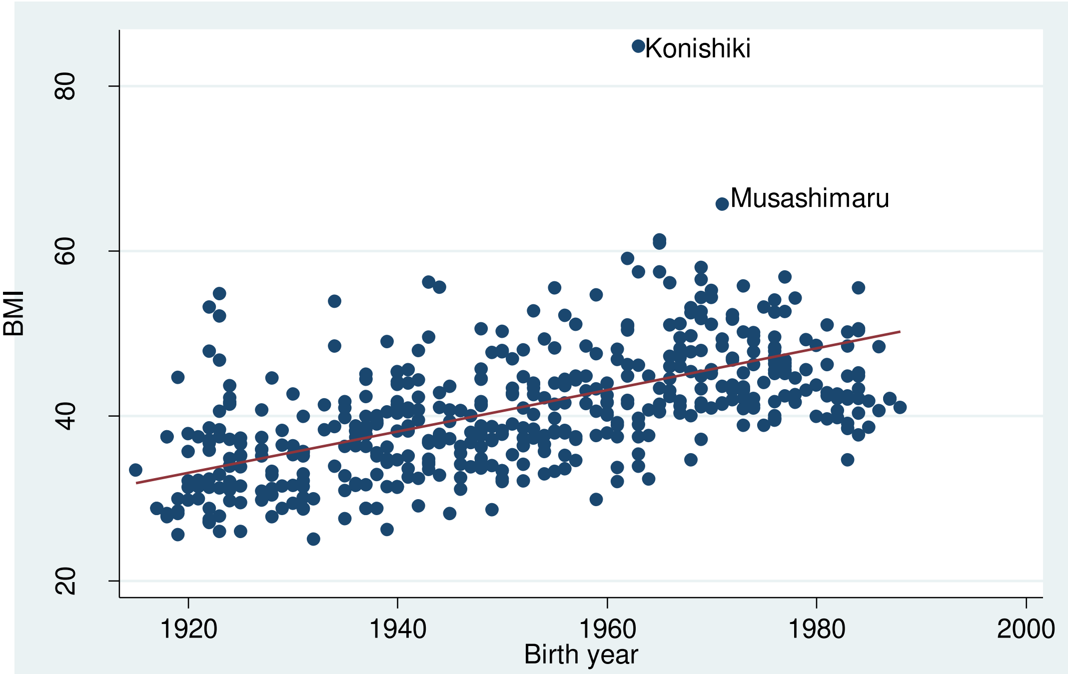


Figure 5. Association between year of birth and BMI.

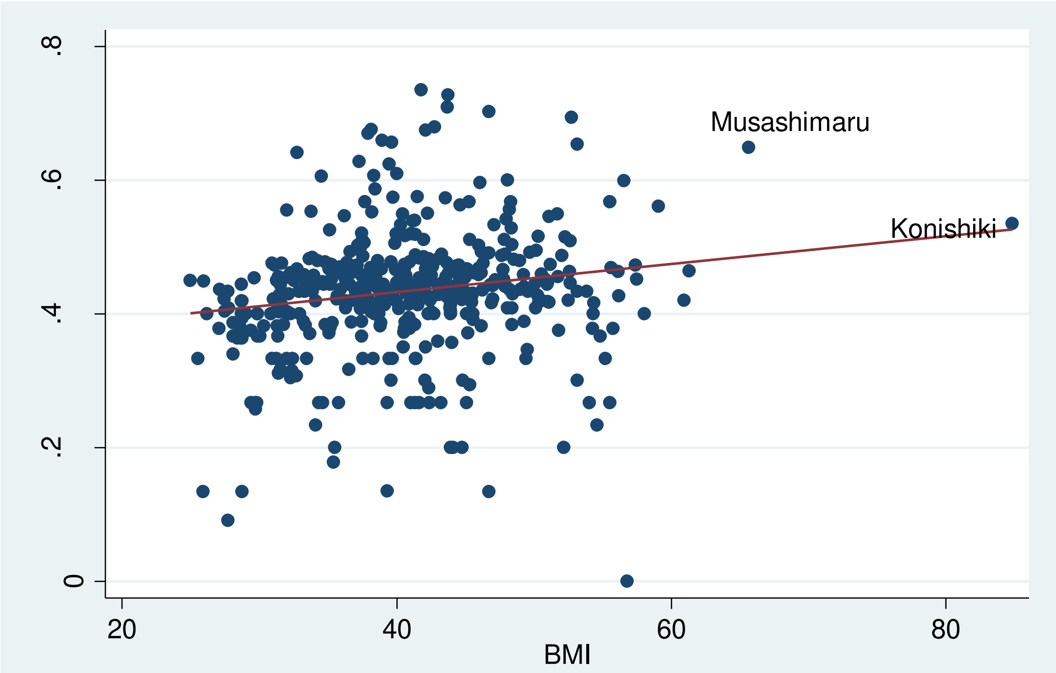


Figure 6. Association between BMI and win rate.

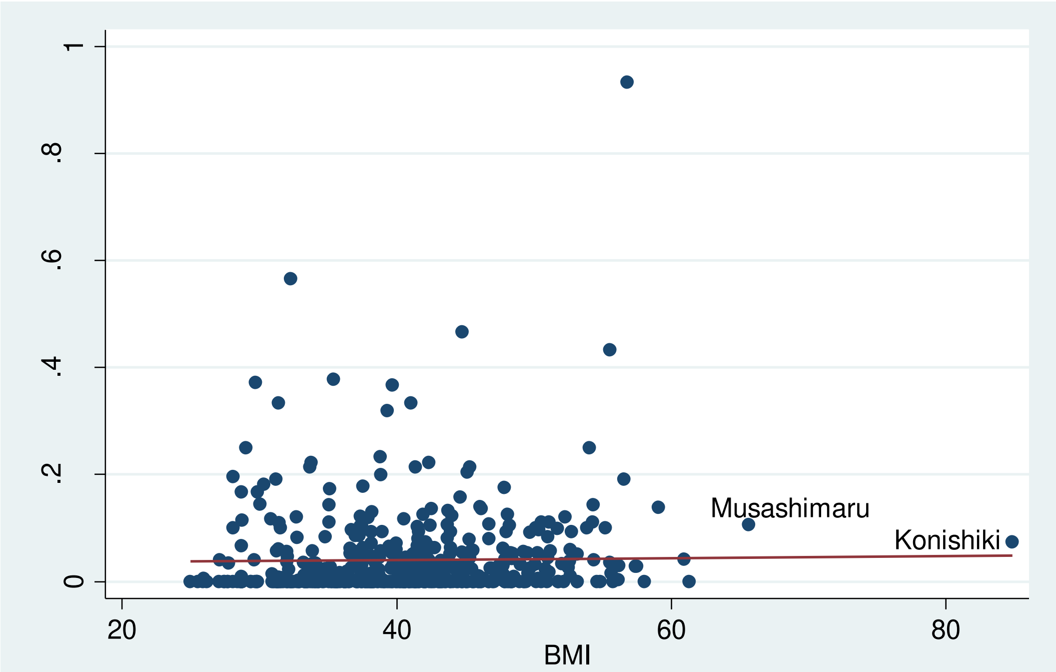


Figure 7. Association between BMI and absence rate.

Table 1
Construction of data used in this paper.

	Rank	Data 1 Sample of Japanese	Data 1 Sample of Foreigners	Data 2 Sample of Japanese	Data 2 Sample of Foreigners
Top division (Makuuchi division)	*Yokozuna*	664 (245)	158 (0)	73 (3)	22 (0)
	Ozeki	1,034 (253)	175 (0)	125 (4)	20 (0)
	Sekiwake	751 (214)	72 (0)	85 (2)	9 (0)
	Komusubi	718 (212)	73 (0)	85 (2)	10 (0)
	Maegashira	9,894 (3,010)	63 (0)	1,154 (34)	99 (0)
Other divisions				2,307 (70)	124 (0)
Total		13,061 (3,934)	1,113 (0)	3,829 (116)	284 (0)

Note: Number in parentheses is from the former period (tournaments in 1945–1967).

Table 2
Comparison of mean values in different periods based on domestic wrestlers.

Variable	Closed period (1945–1967)	International period (1968–2013)	Absolute t-statistic
Win rate (%)	48.3	47.3	2.79***
Absence rate (%)	3.6	4.0	1.27
BMI	37.9	43.6	52.2***
Weight *(kg)*	121	146	65.0***
Height *(cm)*	178	183	43.2***
Age	28.0	27.8	2.99***
Observations	3,934	9,127	

*** indicates significance at 5% and 1% level.

Table 3 Comparison of mean values for domestic and foreign wrestlers in the international period sample

Variable	Japanese	Foreign	Absolute t-statistic
Win rate (%)	47.6	53.6	10.0***
Absence rate (%)	3.9	4.5	1.07
BMI	41.8	48.6	31.2***
Weight (kg)	138	175	46.1***
Height (cm)	181	189	46.4***
Age	27.8	26.1	6.41***
Observations	13,061	1,113	

** and *** indicate significance at 5% and 1% levels, respectively.

Table 4
Determinants of the BMI and weight (fixed effects estimation)

	(1) Full sample	(2) Excluding foreign wrestlers	(3) Full sample	(4) Excluding foreign wrestlers
International period dummy	1.08***	1.18***	1.97*	2.39**
	(2.99)	(3.27)	(1.75)	(2.11)
Height			2.73***	2.70***
			(11.0)	(10.7)
Injury system dummy	0.71***	0.92***	1.23*	1.78**
	(3.25)	(4.12)	(1.66)	(2.31)
Maegashira and lower division dummy		<Reference group>		
Komusubi dummy	1.71***	1.71***	5.34***	5.33***
	(7.12)	(6.39)	(6.56)	(5.96)
Sekiwake dummy	2.12***	2.00***	6.42***	6.12***
	(6.94)	(6.49)	(6.56)	(6.04)
Ozeki dummy	1.70***	1.52***	5.72***	5.08***
	(3.56)	(3.00)	(3.49)	(2.92)
Yokozuna dummy	3.57***	2.92***	12.6***	9.97***
	(4.29)	(3.18)	(3.87)	(2.97)
Age	0.68***	0.66***	2.06***	2.00***
	(30.4)	(29.9)	(24.8)	(25.2)
Constant	20.5***	20.5***	-423***	-416***
	(36.1)	(35.7)	(-9.53)	(-9.31)
Observations	4,113	3,829	4,113	3,829
Number of groups (Number of wrestlers)	356	328	356	328
Log likelihood	0.63	0.63	0.69	0.69

Note: Numbers in parentheses are t-statistics, which are calculated using robust standard errors. *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively.

Table 5
Determinants of the win rate (Random effects Tobit model):

	(1) Excluding foreign wrestlers	(2) Excluding foreign wrestlers. International period	(3) Excluding foreign wrestlers	(4) Excluding foreign wrestlers. International period
BMI	-0.02	-0.01		
	(-0.45)	(-0.29)		
Weight			-0.006	-0.004
			(-0.42)	(-0.27)
Height			0.09	0.08
			(1.45)	(1.25)
Injury system dummy	-0.45	-0.18	-0.62	-0.32
	(-0.61)	(-0.24)	(-0.84)	(-0.42)
Maegashira and lower division dummy		<Reference group>		
Komusubi dummy	-3.42	-3.83*	-3.48	-3.88*
	(-1.58)	(-1.73)	(-1.60)	(-1.75)
Sekiwake dummy	-0.25	-0.14	-0.22	-0.11
	(-0.12)	(-0.07)	(-0.10)	(-0.05)
Ozeki dummy	10.1***	10.1***	10.0***	10.0***
	(5.53)	(5.40)	(5.49)	(5.37)
Yokozuna dummy	15.9***	15.0***	15.9***	14.9***
	(6.68)	(6.12)	(6.67)	(6.12)
Age	-0.93***	-0.92***	-0.94***	-0.93***
	(-12.7)	(-12.3)	(-12.7)	(-12.3)
Constant	75.9***	75.2***	58.1***	59.3***
	(35.6)	(33.7)	(4.77)	(4.75)
Observations	3780	3,669	3780	3,669
Number of groups (Number of wrestlers)	328	315	328	315
Left-censored observations	106	105	106	105
Uncensored observations	3,618	3,511	3,618	3,511

Right-censored observations	56	53	56	53
Log Likelihood	485	463	485	463

Note: Numbers in parentheses are z-statistics, which are calculated using robust standard errors. *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively.

Table 6
Determinants of the absence rate (random effects Tobit model)

	(1) Excluding foreign wrestlers	(2) Excluding foreign wrestlers. International period	(3) Excluding foreign wrestlers	(4) Excluding foreign wrestlers. International period
BMI	3.45***	3.31**		
	(2.70)	(2.56)		
Weight			1.04***	1.00***
			(2.74)	(2.60)
Height			-0.68	-0.62
			(-0.41)	(-0.37)
Injury system dummy	44.3**	38.1**	43.1**	37.0**
	(2.42)	(2.04)	(2.34)	(1.98)
Maegashira and lower division dummy	<Reference group>			
Komusubi dummy	-130.9*	-130.1	-130.9*	-130.1
	(-1.66)	(-1.64)	(-1.67)	(-1.65)
Sekiwake dummy	3.84	5.02	3.73	4.99
	(0.08)	(0.11)	(0.08)	(0.11)
Ozeki dummy	61.9*	63.6*	61.6*	63.4*
	(1.81)	(1.84)	(1.80)	(1.83)
Yokozuna dummy	181.1***	186.7***	180.9***	186.6***
	(4.66)	(4.73)	(4.67)	(4.73)
Age	3.22*	3.10*	3.22*	2.99*
	(1.90)	(1.81)	(1.83)	(1.74)
Constant	-602.1***	-588.6***	-475.3	-472.8
	(-8.10)	(-7.88)	(-1.60)	(-1.58)
Observations	3780	3,669	3780	3,669
Number of groups (Number of wrestlers)	328	315	328	315
Left-censored observations	3,586	3,476	3,586	3,476
Uncensored observations	125	124	125	124

Right-censored observations	69	69	69	69
Log Likelihood	-848	-841	-848	-841

Note: Numbers in parentheses are t-statistics, which are calculated using robust standard errors. ** and *** indicate significance at 5% and 1% levels, respectively. Hansen J statistics are used in the over-identification test.

Table 7
Determinants of the win rate (Tobit model): Sample of domestic wrestlers.

	(1) Whole period (1945–2013)	(2) Closed period (1945–1967)	(3) International period (1968–2013)	(4) International period (1968–2003)	(5) Whole period (1945–2013)	(6) Closed period (1945–1967)	(7) International period (1968–2013)	(8) International period (1968–2003)
BMI	0.03	0.21***	0.0003	-0.01				
	(1.39)	(4.03)	(0.01)	(-0.41)				
Weight					0.01	0.08***	-0.0002	-0.004
					(1.26)	(4.78)	(-0.02)	(-0.41)
Height					0.06*	0.10*	0.06	0.07
					(1.82)	(1.82)	(1.46)	(1.52)
Injury system dummy	-1.14***		-0.51	0.21	-1.38***		-0.59	0.02
	(-3.39)		(-1.13)	(0.31)	(-3.93)		(-1.30)	(0.04)
Maegashira dummy				<Reference group>				
Komusubi dummy	-2.10***	-2.66**	-2.08**	-2.18**	-2.15***	-3.08**	-2.11**	-2.21**
	(-2.93)	(-2.00)	(-2.45)	(-2.35)	(-3.00)	(-2.32)	(-2.48)	(-2.37)
Sekiwake dummy	5.77***	5.61***	5.61***	5.64***	5.71***	4.97***	5.61***	5.64***
	(8.18)	(4.23)	(6.74)	(6.16)	(8.10)	(3.73)	(6.73)	(6.16)
Ozeki dummy	13.2***	14.0***	12.9***	14.0***	13.1***	13.4***	12.9***	14.0***
	(21.8)	(11.3)	(18.5)	(17.8)	(21.6)	(10.8)	(18.4)	(17.7)
Yokozuna dummy	15.6***	13.6***	16.2***	16.4***	15.4***	12.5***	16.1***	16.3***
	(21.0)	(10.9)	(17.5)	(17.5)	(20.8)	(9.73)	(17.4)	(17.4)
Age	-0.69***	-0.53***	-0.78***	-0.80***	-0.69***	-0.51***	-0.78***	-0.80***
	(-15.9)	(-7.59)	(-14.0)	(-12.5)	(-16.0)	(-7.31)	(-14.0)	(-12.4)
Constant	63.8***	53.0***	67.2***	67.8***	53.2***	33.0***	56.3***	55.0***
	(38.3)	(17.9)	(30.4)	(27.6)	(9.25)	(3.37)	(7.65)	(6.67)
Observations	13,061	3,934	9,127	7,512	13,061	3,934	9,127	7,512
Left-censored observations	374	92	282	231	374	92	282	231
Uncensored observations	12,629	3,827	8,802	7,239	12,629	3,827	8,802	7,239

Right-censored observations	58	15	43	42	58	15	43	42
Log Likelihood	-55,455	-16,794	-38,647	-31,821	-55,452	-16,786	-38,646	-31,820

Note: Numbers in parentheses are z-statistics. *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively.

Table 8
Determinants of the absence rate (Tobit model): Sample of domestic wrestlers.

	(1) Whole period (1945–2013)	(2) Closed period (1945–1967)	(3) International period (1968–2013)	(4) International period (1968–2003)	(5) Whole period (1945–2013)	(6) Closed period (1945–1967)	(7) International period (1968–2013)	(8) International period (1968–2003)
BMI	1.43***	-1.08	2.84***	2.67***				
	(2.98)	(-1.24)	(4.40)	(3.65)				
Weight					0.46***	-0.25	0.86***	0.81***
					(3.19)	(-0.98)	(4.52)	(3.76)
Height					-0.11	1.06	-0.74	-1.59*
					(-0.20)	(1.30)	(-0.89)	(-1.65)
Injury system dummy	2.42		7.33	26.5*	0.38		6.71	27.1*
	(0.40)		(0.81)	(1.69)	(0.06)		(0.74)	(1.72)
Maegashira dummy	<Reference group>							
Komusubi dummy	-27.3*	-29.7	-25.5	-20.9	-27.5*	-31.3	-25.4	-20.9
	(-1.77)	(-1.17)	(-1.32)	(-0.97)	(-1.78)	(-1.23)	(-1.32)	(-0.96)
Sekiwake dummy	6.92	-3.07	9.36	18.3	6.40	-5.78	9.31	18.2
	(0.52)	(-0.14)	(0.57)	(0.99)	(0.48)	(-0.26)	(0.56)	(0.99)
Ozeki dummy	70.9***	46.4***	83.0***	80.0***	70.3***	44.5***	82.8***	80.2***
	(7.44)	(2.78)	(7.04)	(5.73)	(7.39)	(2.66)	(7.03)	(5.74)
Yokozuna dummy	169.5***	148.7***	178.7***	188.9***	168.5***	144.6***	178.4***	189.3***
	(15.6)	(9.50)	(12.3)	(11.9)	(15.4)	(8.99)	(12.3)	(11.9)
Age	2.50***	4.09***	1.00	0.60	2.50***	4.17***	0.98	0.60
	(3.13)	(3.77)	(0.91)	(0.46)	(3.13)	(3.83)	(0.90)	(0.46)
Constant	-411.4***	-313.3***	-457.9***	-470.8***	-392.2***	-512.3***	-323.5**	-182.5
	(-12.0)	(-6.36)	(-9.47)	(-8.40)	(-3.64)	(-3.44)	(-2.18)	(-1.06)
Observations	13,061	3,934	9,127	7,512	13,061	3,934	9,127	7,512
Left-censored observations	12,206	3,673	8,533	7,037	12,206	3,673	8,533	7,037
Uncensored observations	600	195	405	317	600	195	405	317

Right-censored observations	255	66	189	158	255	66	189	158
Log Likelihood	-6,226	-1,914	-4,297	-3,407	-6,225	-1,914	-4,296	-3,407

Note: Numbers in parentheses are z-statistics. *, ** and *** indicate significance at 10 %, 5% and 1% levels, respectively.

Table 9
Determinants of win rate (IV Tobit model): Sample of domestic wrestlers.

	(1) Whole period (1945–2013)	(2) Closed period (1945–1967)	(3) International period (1968–2013)	(4) International period (1968–2003)	(5) Whole period (1945–2013)	(6) Closed period (1945–1967)	(7) International period (1968–2013)	(8) International period (1968–2003)
BMI	-0.15***	-0.11	-0.01	-0.17*				
	(-2.80)	(-0.77)	(-0.17)	(-1.78)				
Weight					-0.05***	-0.02	-0.01	-0.05**
					(-3.49)	(-0.44)	(-0.54)	(-2.13)
Height					0.15***	0.17***	0.07	0.14**
					(4.06)	(2.74)	(1.55)	(2.49)
Injury system dummy	-0.51		-0.51	0.88	-0.67*		-0.61	0.81
	(-1.38)		(-1.14)	(1.09)	(-1.75)		(-1.34)	(1.00)
Maegashira dummy				<Reference group>				
Komusubi dummy	-1.94***	-1.91	-2.08**	-2.16**	-1.98***	-2.24	-2.10**	-2.19**
	(-2.70)	(-1.40)	(-2.45)	(-2.32)	(-2.75)	(-1.62)	(-2.47)	(-2.35)
Sekiwake dummy	6.12***	6.45***	5.63***	5.87***	6.10***	5.95***	5.66***	5.89***
	(8.60)	(4.69)	(6.72)	(6.34)	(8.57)	(4.23)	(6.76)	(6.38)
Ozeki dummy	13.6***	15.0***	12.9***	14.1***	13.5***	14.6***	12.9***	14.0***
	(22.1)	(11.5)	(18.4)	(17.9)	(22.0)	(10.8)	(18.4)	(17.8)
Yokozuna dummy	15.7***	14.6***	16.2***	16.6***	15.6***	13.7***	16.2***	16.6***
	(21.2)	(11.1)	(17.5)	(17.5)	(20.9)	(9.79)	(17.4)	(17.5)
Age	-0.70***	-0.57***	-0.78***	-0.84***	-0.70***	-0.55***	-0.78***	-0.84***
	(-16.1)	(-7.92)	(-14.0)	(-12.4)	(-16.1)	(-7.63)	(-14.1)	(-12.5)
Constant	71.6***	-66.3***	67.8***	75.0***	44.4***	32.3***	54.9***	49.8***
	(28.1)	(10.5)	(18.3)	(15.6)	(7.33)	(3.29)	(7.15)	(5.79)
Observations	13,061	3,934	9,127	7,512	13,061	3,934	9,127	7,512
Left-censored observations	374	92	282	231	374	92	282	231
Uncensored observations	12,629	3,827	8,802	7,239	12,629	3,827	8,802	7,239

Right-censored observations	58	15	43	42	58	15	43	42
Wald test of exogeneity.	16.2 P-value = 0.00	5.86 P-value = 0.01	0.04 P-value = 0.84	3.07 P-value = 0.07	23.3 P-value = 0.00	5.01 P-value = 0.02	0.36 P-value = 0.54	4.59 P-value = 0.03
Over-identification test	4.47 P-value = 0.11	13.0 P-value = 0.00	14.9 P-value = 0.00	8.51 P-value = 0.01	3.83 P-value = 0.14	14.8 P-value = 0.00	15.7 P-value = 0.00	8.95 P-value = 0.01
Wald Chi-square	1,161	323	842	779	1,171	333	844	782

Note: Numbers in parentheses are t-statistics, which are calculated using robust standard errors. *, ** and *** indicate significance at 10%, 5%, and 1% percent levels, respectively. Amemiya–Lee–Newey minimum chi-square statistics are used in the over-identification test.

Table 10
Determinants of the absence rate (IV Tobit model): Sample of domestic wrestlers.

	(1) Whole period (1945–2013)	(2) Closed period (1945–1967)	(3) International period (1968–2013)	(4) International period (1968–2003)	(5) Whole period (1945–2013)	(6) Closed period (1945–1967)	(7) International period (1968–2013)	(8) International period (1968–2003)
BMI	4.25***	-5.16**	10.2***	12.6***				
	(4.42)	(-2.15)	(6.48)	(6.03)				
Weight					1.19***	-1.59**	2.97***	3.67***
					(4.27)	(-1.96)	(6.54)	(6.23)
Height					-1.21*	2.06**	-3.66***	-5.30***
					(-1.74)	(2.06)	(-3.67)	(-4.43)
Injury system dummy	-6.94		12.0	-17.8	-7.85		10.6	-17.7
	(-1.04)		(1.32)	(-1.00)	(-1.15)		(1.17)	(-0.99)
Maegashira dummy				<Reference group>				
Komusubi dummy	-29.2*	-20.0	-26.8	-22.4	-29.1*	-20.2	-26.9	-22.3
	(-1.89)	(-0.77)	(-1.39)	(-1.02)	(-1.89)	(-0.77)	(-1.39)	(-1.02)
Sekiwake dummy	1.79	7.55	-2.54	3.70	2.13	7.04	-1.91	4.68
	(0.14)	(0.33)	(-0.15)	(0.20)	(0.16)	(0.30)	(-0.11)	(0.25)
Ozeki dummy	64.8***	58.8***	72.8***	75.7***	64.8***	58.8***	72.5***	75.0***
	(6.74)	(3.20)	(6.15)	(5.38)	(6.74)	(3.08)	(6.13)	(5.34)
Yokozuna dummy	166.2***	158.1***	170.0***	172.0***	165.7***	158.4***	170.1***	172.8***
	(15.3)	(9.10)	(11.7)	(10.8)	(15.2)	(8.28)	(11.7)	(10.9)
Age	2.69***	3.55***	1.41	2.81**	2.65***	3.55***	1.37	2.78**
	(3.35)	(3.20)	(1.28)	(2.00)	(3.31)	(3.16)	(1.24)	(1.99)
Constant	-527.5***	-139.2	-788.8***	-914.5***	-293.3***	-511.2***	-103.1	71.4
	(-10.5)	(-1.38)	(-9.23)	(-8.39)	(-2.66)	(-3.46)	(-0.68)	(0.40)
Observations	13,061	3,934	9,127	7,512	13,061	3,934	9,127	7,512
Left-censored observations	12,206	3,673	8,533	7,037	12,206	3,673	8,533	7,037
Uncensored observations	600	195	405	317	600	195	405	317

Right-censored observations	255	66	189	158	255	66	189	158
Wald test of exogeneity.	11.7 P-value = 0.00	3.39 P-value = 0.06	29.5 P-value = 0.00	28.2 P-value = 0.00	9.64 P-value = 0.00	3.00 P-value = 0.08	29.1 P-value = 0.00	30.0 P-value = 0.00
Over-identification test	2.39 P-value = 0.30	3.72 P-value = 0.15	8.48 P-value = 0.01	3.63 P-value = 0.16	2.74 P-value = 0.25	3.82 P-value = 0.14	8.05 P-value = 0.01	3.45 P-value = 0.17
Wald Chi-square	287	104	189	166	287	104	190	167

Note: Numbers in parentheses are t-statistics, which are calculated using robust standard errors. *, ** and *** indicate significance at 10%, 5%, and 1% percent levels, respectively. Amemiya–Lee–Newey minimum chi-square statistics are used in the over-identification test.