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Title Page

1) Title: Projecting future supply and demand for physical therapists in Japan using system dynamics

2) Full names (first and surname) of all authors including academic degrees and affiliation(s)

Yasuhiro Morii[1)], M.S in Health Sciences

Tomoki Ishikawa[2)], MBA, M.S in Health Sciences

Teppei Suzuki[2)], MBA, M.S in Health Sciences

Shintaro Tsuji[2)], PhD in Health Sciences

Masanori Yamanaka[2)], PhD in Medicine

Katsuhiko Ogasawara[2)*], MBA, PhD in Health Sciences

1) Graduate School of Health Sciences, Hokkaido University

2) Faculty of Health Sciences, Hokkaido University

*Correspondence

---

3) Name, mailing and email addresses, telephone and fax numbers of corresponding author (with whom all correspondence will take place unless other arrangements are made)

Katsuhiko Ogasawara

oga@hs.hokudai.ac.jp

Faculty of Health Sciences, Hokkaido University

N12W5, Kita-Ku, Sapporo, Hokkaido, Japan

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Title: Projecting the future supply and demand for physical therapists in Japan using system dynamics

Objectives: Japan is the oldest country in the world, and its demand for medical care is expected to increase. Although a clear vision regarding the supply and demand for physical therapy services is necessary, there has been no research that forecasts the supply and demand for physical therapists in Japan. Consensus has not been reached on whether the supply of physical therapists is sufficient. This study projects this supply and demand to provide medical policymakers with basic data.

Methods: A system dynamics model was created to predict the number of physical therapists working in hospitals and clinics in Japan from 2014 to 2040. The future demand for physical therapy was estimated using the rehabilitation service utilization data from Open National Database, a publicly available nationwide health claims database. Sufficiency rates (supply/demand) were calculated, and sensitivity analysis was conducted on supply-related parameters.

Results: The number of physical therapists was projected to be 1.74 and 2.54 times greater in 2025 and 2040, respectively, than in 2014. The sufficiency rates were 1.72, 2.39, and 3.30 in 2015, 2025, and 2040, respectively. The sensitivity analysis revealed that attrition rates had the greatest effects on sufficiency.

Conclusions: Although the current supply appears to be needed, considering the expected increase and uncertainty in medical needs. However, there is a possibility of a future oversupply, especially after 2025, when the rate of increase in demand will lessen. Further studies are required to evaluate the distribution of physical therapists among regions and specialties.

Introduction

Developed countries face the problem of aging societies [1]. Among developed countries, the United Nations reported that Japan is, and will continue to be, the oldest country in the world [1]. Aging societies result in increased medical demand [2], even as the National Institute of Population and Social Security Research (IPSS) estimated that Japan's total population will decrease by approximately 13% during the 2015-2040 [3].

The demand for rehabilitation is rising with the aging population and improvements in medical treatment and

management [4,5]. Therefore, it is necessary to have a clear vision of the supply and demand for rehabilitation services. Rehabilitation is an essential medical service for promoting people's health and daily living activities [6]. Landry et al. projected the supply and demand for physical therapists (PTs), a major rehabilitation provider, after the implementation of the Affordable Care Act in the United States [7]. Zimbelman et al. assessed the PT sufficiency rates in each region in the United States [8].

In Japan, the number of schools for PT licensure, as well as PT enrollment, increased rapidly after 1999 [9], and several reports mentioned an oversupply of PTs [10]. On the other hand, the Ministry of Health, Labor, and Welfare (MHLW) mentioned a possible PT shortage caused by the aging of society [11]. There is currently no research that forecasts future PT supply and demand, and consensus has yet to be reached regarding PT sufficiency.

System dynamics (SD) is a method for projecting the amount of resources [12]. SD was developed by JW Forrester in 1956 [13] and then applied to other fields such as the environment [14] and urban development [15]. SD modeling has previously been applied to projections of medical human resources, such as the future supply and demand for ophthalmologists in Singapore [16], specialists in Spain [17], physicians in Australia [18] and England [19], and registered nurses in Canada [20]. In Japan, Ishikawa et al. projected the future number of physicians [21], and Arazeki et al. projected the future number of radiologic technologists [22]. The merits of using SD modeling are that dynamic relationships such as feedback can be simulated, and that the values of inputs are dependent on past data, which is different from regression or time series analysis [15]. Since the parameters related to the supply of PTs (enrollment, attrition rates) vary over time, SD modeling is suitable for PT supply projection because SD models can reflect the trends (e.g. policy changes) in those parameters.

Recently, parts of data from the National Database (NDB), a nationwide database of health claims in Japan, has been made available to promote healthcare-related research (i.e., Open NDB) [23]. Since data on the number of rehabilitation services provided are available, utilization-based projection of the demand for PTs has become possible.

In this research, to provide basic data for determining PT supply and demand for medical policymakers, the future supply of PTs is projected using a career path model that uses SD, and the future demand for PTs is projected from the Open NDB data. Afterwards, the projected supply of, and demand for PTs are compared for sufficiency

evaluation.

Methods

Prediction Model for the Supply of PTs

Our model is based on the concept of SD modeling, a methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues [12]. A central tenet of SD modeling is “stocks” (accumulations) such as the number of PTs and graduate students, and “flows”, which are variables that depict the rates of change in “stocks” in a particular period. The behavior of the problem of special interest is initially expressed using stocks and flows, and thereafter is calculated by sets of differential and algebraic equations, as the integration of net inflows. In Equation 1, Inflow (t) and Outflow (t) denote the values of inflows and outflows at any point (i.e., its time derivative) between the initial time and the present time t [15].

The left side of Figure 1 shows the supply projection model scheme, and Figure 2 shows the model used in the simulation software (Stella version 8.1.1 from isee systems, Lebanon, NH, USA) for the supply projection. The model is based on the career paths of PTs in Japan, considering parameters related to the supply of PTs (e.g., enrollments, attrition). The model begins in 2014 and projects the number of PTs working at hospitals and clinics in Japan up to 2040. The initial input of the number of PTs (77,139.8) was obtained [24]. The module is a continuous time model, and changes in the number of PTs are caused by attrition (which includes any reason for leaving such as retirement and death), the employment of new students who pass the national exam (the annual official exam), and students in graduate schools. The scheme reflects the educational path for PTs in Japan, in which students enter school, graduate, take the national exam, and are hired four years after starting if they pass the exam. During this process, the number of students in the model decreases if they “drop out of school,” “fail the exam,” or are “not employed.” If students fail the national exam, they can take the exam again in the next year. In choosing their workplaces, most of them choose hospitals, clinics, or nursing care facilities. In this simulation, the number of PTs working in hospitals and clinics is counted. Some students enter graduate school after the 4-year course, and they often go to graduate school while they work as clinical PTs [25]. In this model, students who work as clinical PTs count as PTs. Table 1 shows the list of parameters used in the supply projection model, their definitions, their data sources, the years the data sources were published, and the values of the parameter inputs in the model [9, 24-28].

Efforts were made to use the latest data, in order to reflect the latest trends. The number of PTs was calculated as the number of full-time equivalents. The projected number of PTs per 10,000 people was calculated based on population estimates by IPSS [3]

$$\frac{d}{dt}(Stock) = Inflow(t) - Outflow(t) \qquad \text{Equation (1)}$$

The parameters in the supply prediction model, such as attrition rate and national exam pass rate, can change randomly or through policies. Landry et al. simulated the supply of PTs in the United States under three scenarios with varying attrition rates [7]. Murphy et al. estimated the shortage of registered nurses in Canada from 2007 to 2022, and conducted sensitivity analyses on productivity and enrollments [20]. Human resource planning should be based on an understanding of the possible effects of changes caused by unforeseen circumstances or policy changes. In this research, policy scenario tests were conducted by changing one or two of the parameters shown in Table 2. In the highest growth case, all the parameter inputs in Table 2 were changed so as to increase the supply of PTs, while in the lowest growth case, all the parameter inputs were changed so as to decrease the supply of PTs. Table 2 shows, for all the policy tests in this study, the range of the changes in values of the parameters from the base case. Table 1 gives the values of the parameters in the base case.

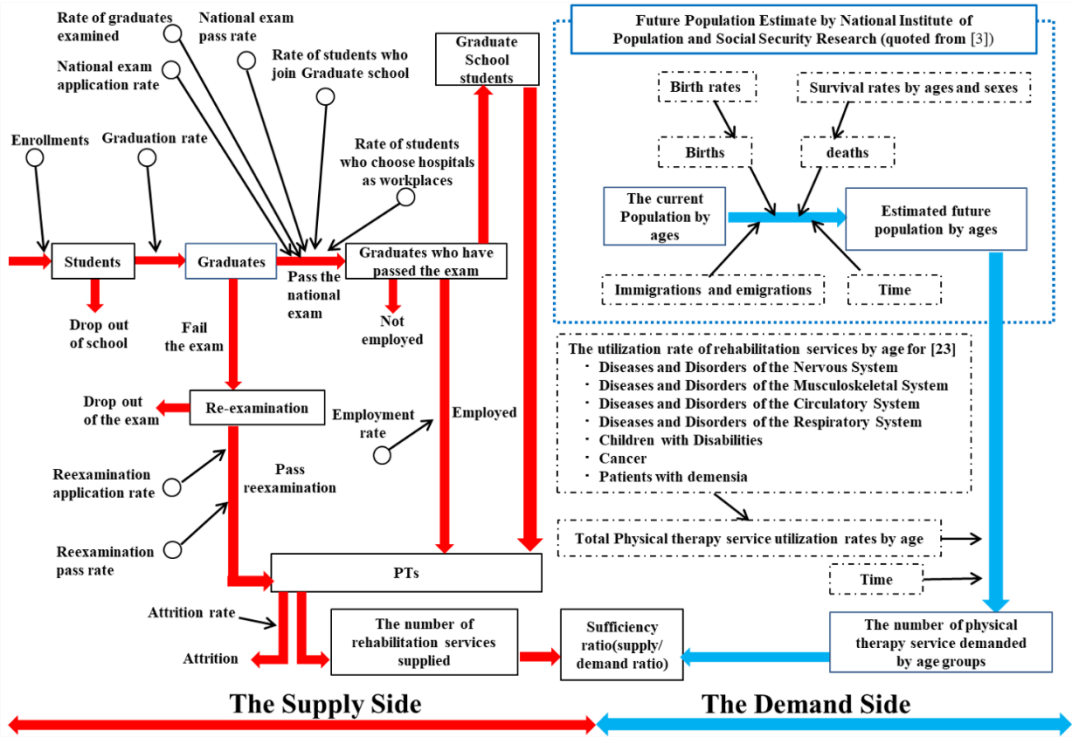


Figure1: The scheme of the supply projection and the demand projection

Figure Legend: Figure 1 shows the scheme of the projection of supply and demand for physical therapists in Japan in this study.

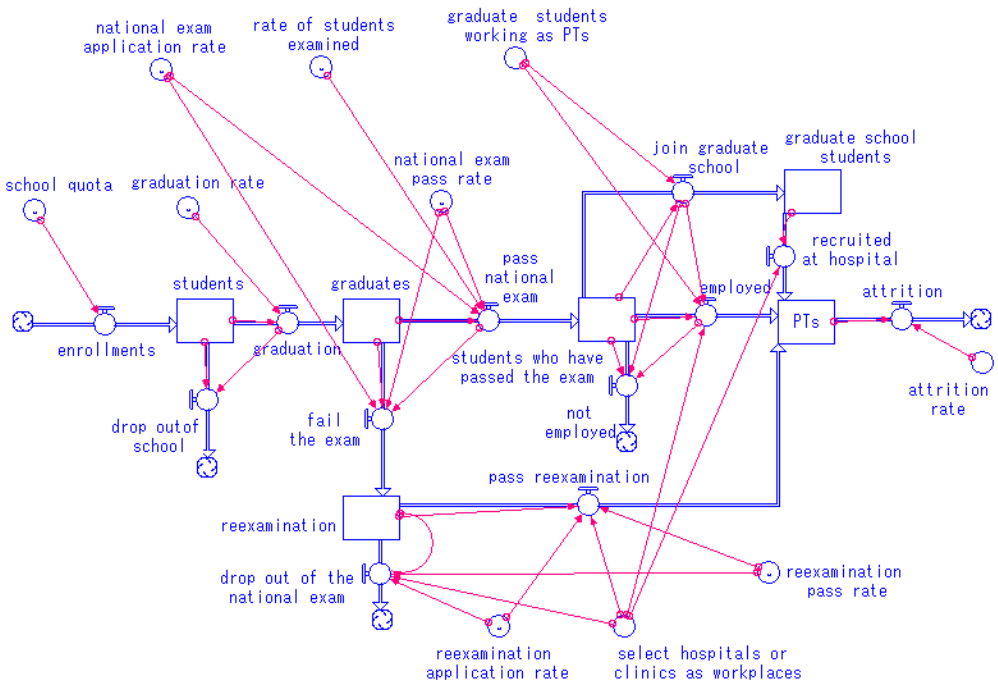


Figure2: The supply projection model of physical therapists in Japan.

Figure Legend: The supply projection model of physical therapists in Japan is shown in Figure 2. The model is based on the career path of physical therapists in Japan. The simulation is based on the concept of system dynamics. The model consists of stock such as the number of students, and students who pass the national exam. The definition, values, and data sources of the parameters are listed in Table 1.

Table1. A list of the parameters used in the supply projection and the demand projection

	Parameter	Definition	source	Value	Year
The supply side	Enrollments		9	13435-14051	2014-2018
	Graduation Rate	Graduation in year n / enrollment in year n-4	9	0.877	2013-2017
	National Exam Application Rate	Graduates who apply for the exam / Graduates	9, 23	0.924	2013-2017

	Rate of students who take exam	Applicants who take the exam / Graduates who applied for the national exam	9	0.954	2013-2017
	National exam Pass Rate	Applicants who pass the national exam / Applicants who take exam	9	0.891	2013-2017
	Re-exam Application rate	Graduates who re-apply for the national exam in a year n / Graduate who failed the exam in a year n-1	9	0.736	2013-2017
	Re-exam rate	Graduate who re-take the national exam in year n /Graduates who re-apply for the national exam in year n	26	0.965	2013-2017
	Re-exam pass rate	Graduate who pass the re-exammination in a year n /Graduates who re-take National exam in a year n	26	0.37	2013-2017
	Rate of Graduates who join graduate school	Graduates who go to graduate school / Graduates who have passed the national exam	27	0.063	2010

	Graduate school students working as clinical PTs	Graduates school students who work at a hospital or a clinic (counted as a PT) / Graduates who go to graduate school	27	0.747	2010
	Rate of graduates employed	Graduates who are employed as a PT / Graduates who pass the national exam	25	0.992	2015
	Attrition Rate	(Graduates who pass the national exam (n) - increase in the number of PTs (n - (n-1)) / the number of PTs (n)	9,24	0.019	2010-2014
The demand side	Rate of choosing hospital or clinics as a workplace	Increase in the number of PTs in hospitals in clinics / (Increase in the number of PTs in hospitals in clinics + Increase in the number of PTs in nursing care facilities	24, 28	0.711	2010-2014
	Estimated future population by age	The future population estimated by National Institute of Population and Social Security Research	3		2015
	The number of rehabilitation service utilization by age by types of services	The rehabilitation service utilization data from the National Database	23		2016
	The utilization rate for rehabilitation services by age	The number of rehabilitation service utilization by age / Estimated future population by age	3, 23		2015-2016

Table2: The sensitivity ranges used in the policy scenario tests

Parameter	Changes from the base case	
	Lower range	Higher range
Attrition rate	1%	-1%
Graduation Rate	-10%	10%
Enrollments	-10%	10%
National Exam Pass Rate	-10%	10%

Supply Model Validation Test

The model's validity in terms of its structure and its behavior was tested according to previous studies [15, 21]. In the structure test, the model's structure was discussed and evaluated for validity by six researchers experienced in simulations. They included two PTs, one with more than 30 years of clinical experience. In the behavior test, the number of PTs, attritions, the number of students who passed the national exam, and the number of students who graduated from school from 2003 to 2014, were simulated using the model and then compared to the actual number of PTs in each respective year. The error rates were calculated using Equation 2. The root mean square error (RMSE), defined in Equation 3, evaluated the validity of the model. In Equation 3, "n" denotes the number of years in which the validity is tested, and "t" denotes time. An RMSE that is smaller than 0.1 confirms the validity of the model [15].

$$e = \frac{\left|(\hat{y}_t - y_t)\right|}{y_t} \qquad \text{Equation (2)}$$

$$RMSE = \sqrt{\frac{\sum_1^n e_t^{\,2}}{n}} \qquad \text{Equation (3)}$$

Projection of the Demand for PTs

The scheme is presented on the right side of Figure 1. Table 1 lists the parameters used for the demand projection. To reflect future demographic changes in Japan, the model used data on future population estimates of Japan by the IPSS [3]. Their population estimate was based on the cohort-component method, which considers deaths, births, net migration (Figure 1). Data on the number of rehabilitation services (20 minutes per service) utilized by each age group were obtained from the Open NDB [23]. The sum of the number of all types of rehabilitation services for each age group (e.g. stroke rehabilitation, cancer rehabilitation) was calculated. The data included the quantity of rehabilitation services provided by physical therapists, occupational therapists, and speech therapists. We assumed that the quantity of rehabilitation services provided by PTs did not differ from those of other rehabilitation professionals. We calculated the average number of physical therapy services per person in each age group by dividing the total number of rehabilitation services for each age group in 2015 by the population of that age group in

2015. We projected demand for PTs by multiplying the average physical therapy utilization rate in each age group by its estimated future population [3]. We assumed that the per-person rehabilitation utilization rate for each age group did not change. To consider the trend of the demand for PTs with the estimated demographic changes in Japan, data on the estimated future population of Japan and its elderly population (people over 65 years old) were derived from the source [3].

PT Sufficiency Rate

The projected supply of PTs was converted into the number of physical therapy services provided. We assumed that each PT provided 18 PT services per day, based on description in the National Health Insurance system. We also assumed that each PT worked 253.8 days per year, based on a previous survey by MHLW[29]. The sufficiency of PTs was determined by the sufficiency rate (the supply/demand ratio).

Results

The Future Supply of PTs

The projected number of PTs was 134,527 in 2025 and 196,166 in 2040, which was 1.74 times and 2.54 times as large as that in 2015 (Figure 3), respectively. The number of PTs per 10,000 people was 6.5 in 2015 (8.2 when nursing care sector is included), 8.8 in 2020, 11.0 in 2025, 13.2 in 2030, 15.4 in 2035, and 17.7 in 2040. The number of PTs translates into 379,465,466 rehabilitation services in 2015, 614,571,365 in 2025, and 896,163,886 in 2040. The results of the policy scenario tests are shown as a tornado chart, in order to visualize the effects of changes in the parameters on the supply of PTs (Figure 4-a). In 2040, compared with the base case (when the projected number of PTs was 0 in Figure 4), the number of PTs varied from +32,881 to -27,005 when the attrition rate changed by 10%, from +13,470 to -18,077 when the graduation rate changed by 10%, from +11,084 to -15,691 when the enrollment changed by 10%, and from +10,354 to -14,961 when the national exam pass rate changed by 10%. In summary, the attrition rate has the largest effect on future supply of PTs, followed by enrollments, the graduation rate, and the national exam pass rate. Figure 4-b gives the results of the multi-way policy scenario tests.

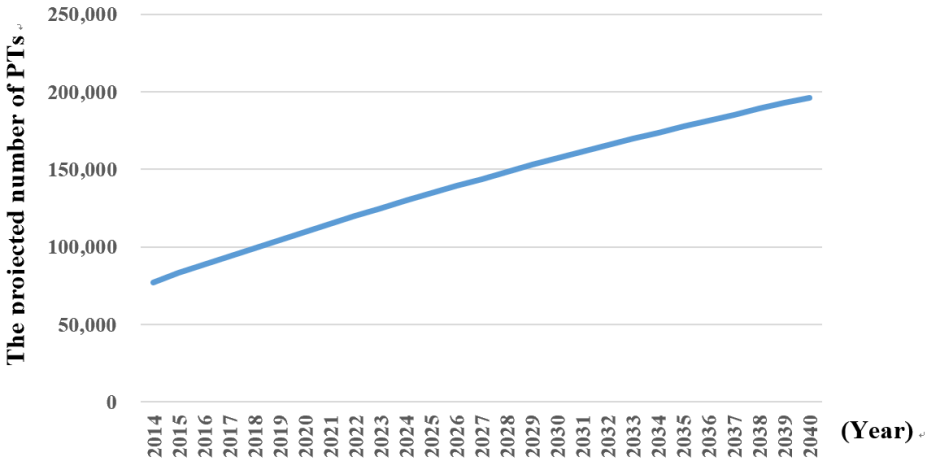


Figure 3: The projected number of physical therapists s from 2014 to 2040 in the base case

Figure Legend: Figure3 shows the projected number of physical therapists s from 2014 to 2040

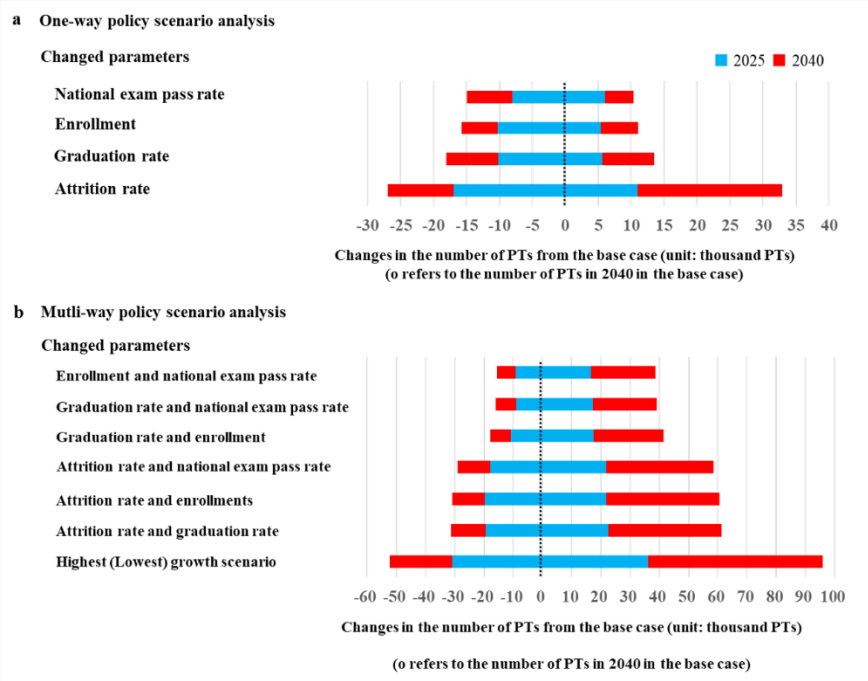


Figure 4: The projected number of physical therapists in 2040 in different scenarios ((a) one-way, and (b) multi-way policy scenario analysis (0 refers to the number of physical therapists in the base case)).

The results of (a) one-way (b) multi-way policy scenario tests are shown in Figure 4. The results are shown as changes in the number of physical therapists in 2025 and 2040. In the graph, 0 refers to the base case.

Current and Future Demand for PTs

Figure 5 displays the estimated average number of physical therapy services for each age group. The results showed that the number becomes larger as people get older, growing especially rapidly after age 50. The estimated demand for PTs in 2020 is 240,538,207 rehabilitation services; 256,831,170 in 2025; 267,987,900 in 2030; 272,859,570 in 2035; and 271,658,276 in 2040. When we compared demand with quantity in 2015, the estimated demand ratio for PTs was higher by 1.09 times in 2020, 1.16 times in 2025, 1.24 times in 2035, and 1.23 times in 2040 (Figure 6), peaking in 2035. The IPSS [3] estimated that Japan's population will decrease by 13% from 2015 to 2040, while the population over 65 years old will increase by approximately 15% (Figure 6).

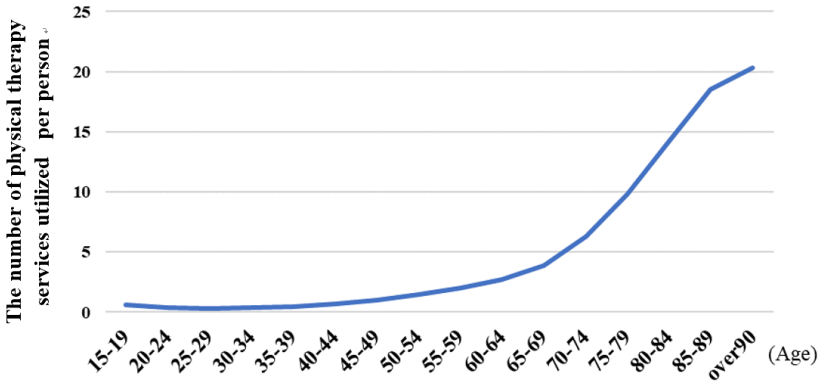


Figure 5. The average quantity of physical therapy service utilization by age groups

Figure 5 shows the number of physical therapy services utilized by per person at each age group.

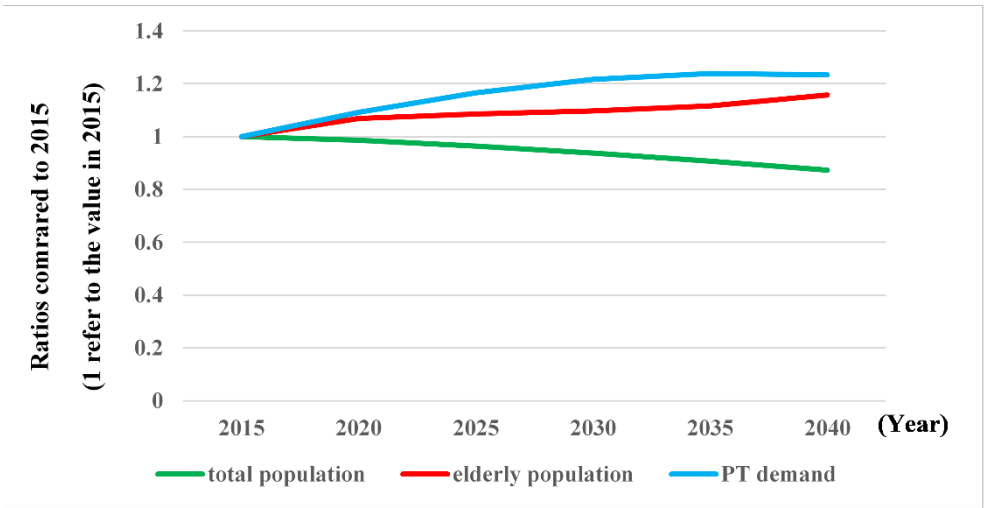


Figure 6 shows the time trends of the estimated demand for physical therapists from 2015 to 2040, and the estimated total Japanese population and the estimated Japanese population who are older than 65 [3].

Sufficiency Rates

In the base case, the sufficiency rates were 1.72 in 2015, 2.39 in 2025, and 3.30 in 2040 (Figure 7). Figures 7 and 8 present the results of the policy scenario analyses. When the attrition rate changed by ±10%, the sufficiency rate would be 2.21 or 2.58 in 2025, and 2.83 or 3.85 in 2040 (Figure 7-a). When enrollments changed by ±10%, the sufficiency rate would be 2.47 or 2.28 in 2025, and 3.49 or 3.03 in 2040 (Figure 7-b). When the graduation rate changed by ±10%, the sufficiency rate would be 2.49 or 2.25 in 2025, and 3.53 or 2.99 in 2040 (Figure 7-c). When the national exam pass rate changed by ±10%, the sufficiency rate would be 2.48 or 2.27 in 2025, and 3.04 or 3.47 in 2040 (Figure 7-d). Figure 8 gives the results of the multi-way sensitivity analyses.

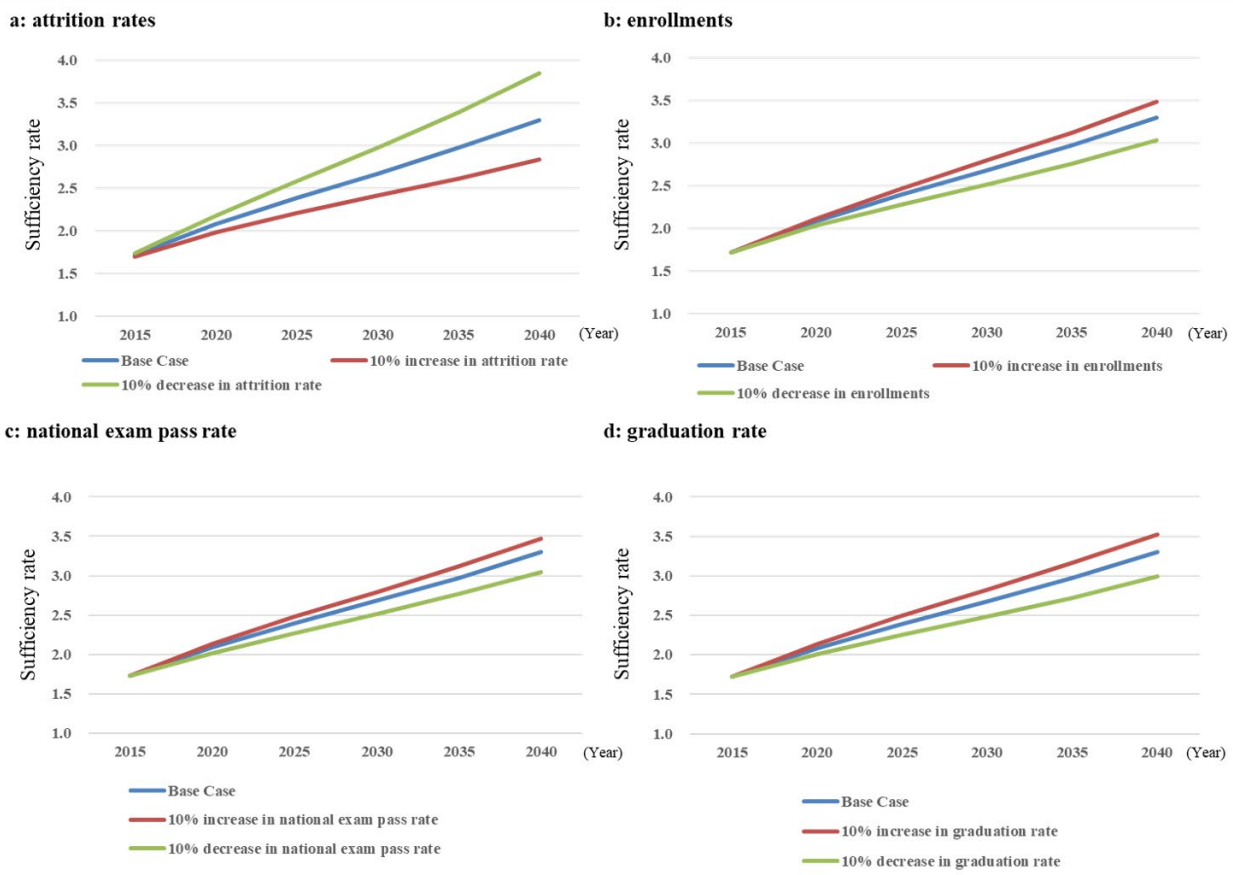
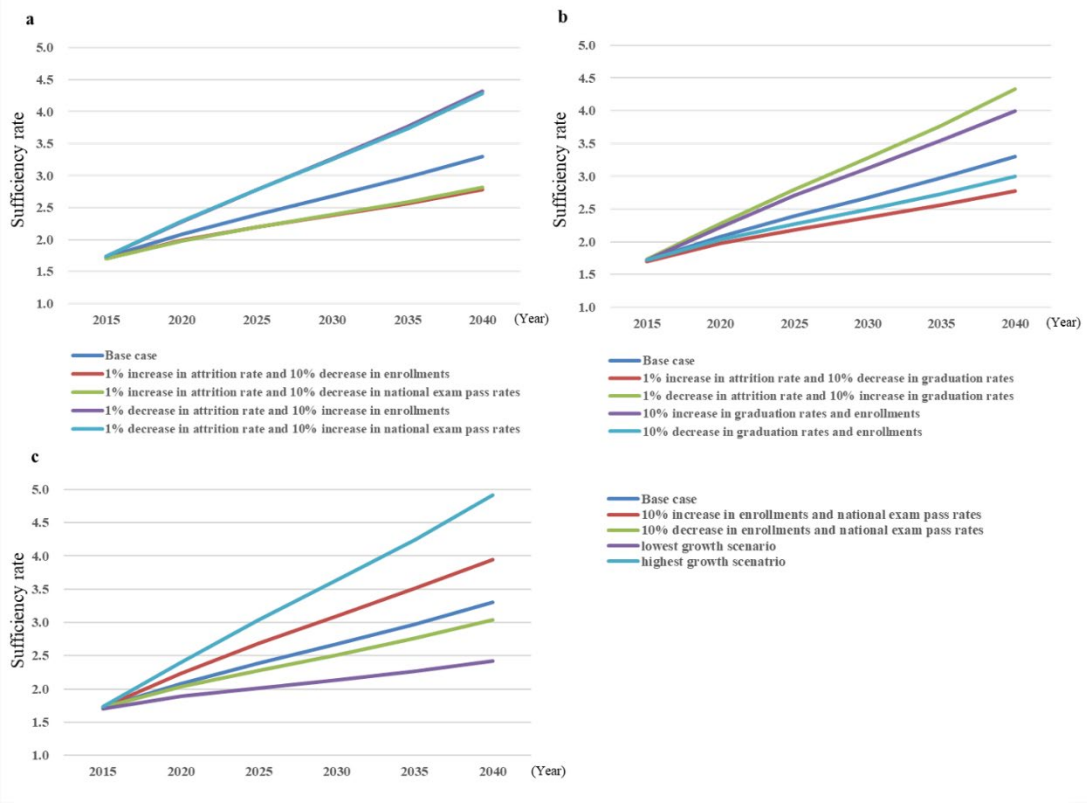


Figure 7. The results of one-way policy scenario analysis on the sufficiency rates

Figure 7 shows the sufficiency rates of physical therapists from 2015 to 2040 in different scenarios of one-way policy scenario analyses.



Model

Figure 8. The results of multi-way policy scenario analysis on the sufficiency rates

Figure 8 shows the sufficiency rates from 2015 to 2040 in different scenarios of multi-way policy scenario analyses.

Validation

The behavior test for validation produced error rates for the number of PTs of 0.006 in 2005, 0.0009 in 2008, 0.003 in 2011, and 0.03 in 2014, for a calculated RMSE of 0.019. Figure 9 shows the predicted and the observed numbers for the parameter tests. For every parameter, the RMSE was lower than 0.1. Online Supplement gives the error rates for the other parameters tested.

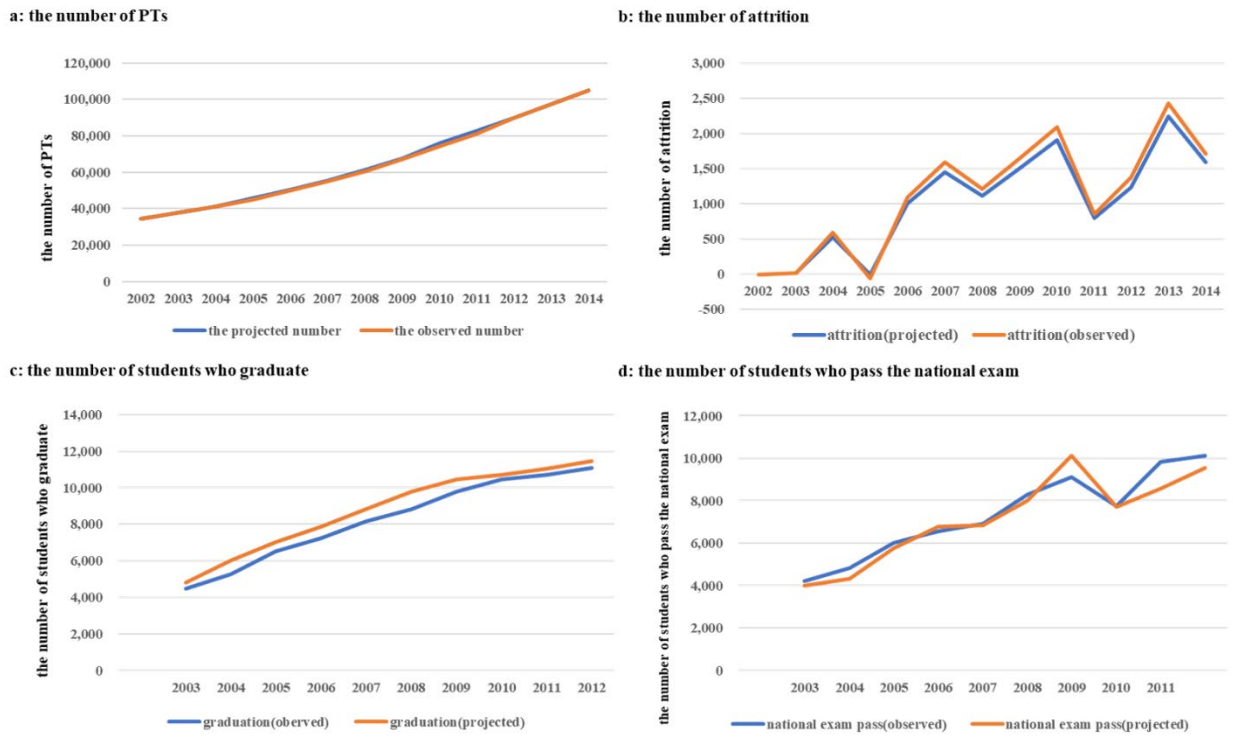


Figure 9: the results of model behavior validation tests

Figure Legend: Figure 3 shows the results of model behavior validation tests for (a): the number of physical therapists, (b) attritions, (c) the number of students who graduate, and (d) the number of students who pass the national exam. The results are shown as time trends, and the projected results and the actual data are compared.

Discussion

This study projected the future supply of PTs in Japan using SD modeling, and projected the current and future demand for PTs [23]. Since the RMSE was less than 0.1, the result confirmed the validity of the model's behavior [15]. In addition, six researchers experienced in simulations evaluated the model's structure. However, the factors relevant to the supply of PTs vary over time, so continuous refinements are necessary. SD modeling has been used to predict the future supply and demand for healthcare professionals in, not only Japan [21-22], but also other countries [16-20]. SD modeling is an appropriate method for predicting medical resource supplies because, although the

parameters related to the supply of healthcare resources (e.g., enrollment, attrition) vary over time, recent trends in those parameters can be reflected in SD modeling's assumptions. However, even though the methods in this study are applicable for PTs in other countries, applications should be conducted with caution because some parts of the model structure used to predict PT supply and demand could differ among countries. For example, the projection model in this study did not contain net migration, because net migration accounted for a very small segment of PTs in Japan, and we lacked the data. On the other hand, Kanchanachitra reported that, in Singapore, immigration from neighboring Asian countries partly compensated for PT shortages [30]. In some countries, the inflows and outflows of PTs among countries are parameters that should be considered. On the demand side, Landry et al. included the percentage of the population with insurance in their model [7], a parameter that was not necessary in this study because Japan has universal healthcare insurance. Jesus et al. emphasized that the supply and demand for PTs needs to be interpreted within the context of each country [32]. Model structures should carefully consider the situation in that country.

The results of the policy scenario tests revealed that attrition rates had the greatest effect on the supply of PTs. Landry et al. examined the supply and demand for PTs in the United States under three different attrition rates [7]. Their results showed that, under their highest attrition rate, a PT shortage was possible. This study supports those results. Since these parameters are partly under political control, these results are useful for determining future values of the parameters. In addition, this study conducted multi-way policy scenario tests on the future supply of PTs, and the results are very important because the parameters are likely to change simultaneously.

The demand for PTs is estimated to increase during the study period. The quantity of PT service utilization per person by age group increased rapidly as people got older (Figure 5). These results indicated that aging might have a big effect on the demand for PTs. The increase in the demand for PTs was highest between 2015 and 2025. This result is attributed to by the fact that all baby boomers will be over 75 by that time, and the number of elderly people will increase sharply during that period. The increase in the demand for PTs was lower between 2025 and 2035 (Figure 6). During that period, while the elderly population will increase, the total population will decrease more rapidly than in the 2015-2025 period. The demand for PTs peaked in 2035, and did not increase until 2040. The result indicated that a decrease in the total population would offset the effect of the increased elderly population on the demand for PTs. The model in this study included the expected demographic changes in its demand projections

because future demographic changes are expected to be the main drivers of medical demand in Japan [2]. Japan is a unique country because it has the highest aging rate in the world [1]. In the future, other developed countries are also expected to suffer from the problems of aging and a decreasing population [31]. Therefore, the PT demand in Japan will be a pioneer case for other countries, because this is the first study that included expected demographic changes in Japan when projecting the demand for PTs. Medical policymakers in other countries can refer to these results.

In the base case, the sufficiency rate in 2015 was 1.72. Previous research noted that the number of registered PTs in Portugal in 2014 was 7.8, which was higher than the 6.5 in the United States, 1.8 in Singapore, and <0.1 in Bangladesh, and mentioned that the figures were explained by high demand for PTs caused by aging populations in Portugal [32]. The number in Japan in 2014 was approximately 8.2 when including PTs in the nursing care sector [24, 27] (6.5 for PTs working at hospitals and clinics), close to Portugal's [32]. The figure can also be explained by the demand caused by Japan's aging population. Moreover, considering the uncertainty in demand and the expansion of PTs' work, PT supply needs to have a surplus to some extent. However, in the base case, the sufficiency rate in 2025 was 2.39, and around 3.30 in 2040. The number of PTs per 10,000 people was 11.0 in 2025 and 17.7 in 2040. These figures are much higher than Portugal's in 2013, where Jesus et al mentioned the market was saturated [32]. Gupta et al. reported the density of allied health professionals associated with rehabilitation per 10,000 people in 76 countries. The result revealed that Japan had the second highest density after Finland [33]. Our results showed that future supply largely surpassed future demand, especially after 2035-2040, when the demand for PTs stopped increasing. Therefore, there is a possibility of a future oversupply of PTs in Japan. Jesus et al. considered the supply and demand for PTs in the United States, Singapore, Portugal, and Bangladesh, and their result indicated that the number of PT graduates per 10,000 people in Portugal in 2013 was approximately 0.7, much larger than in the other three countries (0.1-0.3) [32]. In Japan, the number of schools for PTs and graduates increased rapidly after deregulation in 1999 [9], and the number of PT graduates per 10,000 people in Japan in 2013 was 0.87 [3,9], larger than in Portugal. The possible future oversupply can be attributed to the number of graduates. The future supply of PTs needs to be controlled, based on the expected demand for PTs. The policy tests in this study clarified how changes in related parameters could affect future sufficiency rates (Figure 8). The results will be important in determining future supply based on the expected demand.

Although this study uncovered a possible oversupply of PTs in Japan in the future, the perspective of relative

shortages needs to be considered. For example, Zimbelman et al. analyzed the supply and demand for PTs in the United States, and reported that the greatest shortages would be in states in the south and west [8]. Morii et al. reported that, within the medical areas in Hokkaido, Japan, PTs were distributed more unequally than doctors and nurses [34]. Since regional disparities in the supply of PTs are possible, further research is required to study the relative sufficiency of PTs in Japan by region. Barber et al. forecasted the future supply and demand of medical specialists, and found that the greatest shortages would be in specialties such as anesthesiology, orthopedic and traumatic surgery, and pediatric surgery [17]. Ishikawa et al. forecasted the future demand for physicians in Japan and found that there would still be a shortage of obstetrics and gynecology physicians in 2030, although the overall supply of clinical physicians would be sufficient [21]. PTs work in hospitals, hospital departments (e.g. for stroke rehabilitation, rehabilitation after orthopedic surgery), and the nursing care sector. Future research needs to focus on the distribution of PTs among specialties.

This is the first study to project the future supply and demand for PTs in Japan, where unique demographic changes are expected. Therefore, its results and methodology will be of great importance when considering the supply and demand of PTs in Japan.

However, this research has several limitations. First, due to a lack of data, the PTs working in nursing care facilities were not within the scope of the analysis. Second, occupational therapists and speech therapists also provide rehabilitation services although these medical professions also provide rehabilitation services. Further research is required to predict the future supply and demand for rehabilitation services more comprehensively, but the methodology in this study is also applicable for that analysis. Lastly, several parameters in the model were based on assumptions that could be improved with an increase in the available data; this would further improve the accuracy of the model.

Conclusion

This study, to provide basic data for medical policymakers, projected the future supply of PTs using SD modeling, and the future demand for PTs using Open NDB data. Then, we compared the projected supply and demand for PTs for sufficiency evaluation. The results revealed that, in the future, the supply of PTs will surpass the demand to a large extent—especially after 2035, when the demand is not expected to increase. Because the result indicates a

possible oversupply of PTs in the future, the number of PTs needs to be managed, based on an understanding of the demand projection. Further research needs to focus on relative inequality, such as regional maldistribution and maldistribution among specialties.

Abbreviations

PT: physical therapists, IPSS: National Institute of Population and Social Security Research, MHLW: the Ministry of Health, Labour and Welfare, SD: System Dynamics, NDB: the National Database, Open NDB: the Open National Database, RMSE: root mean square error

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