Original Article

Correlation between the beverage serving activities and the dental use of health care resources of National Health Insurance for common oral diseases

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Abstract Background/purpose: Taiwanese get use to drinking hand-shaken beverages. However, excessive sugar intake is strongly associated with the occurrence of dental caries. This study evaluated the correlation between the beverage serving activities and the dental use of National Health Insurance (NHI) for common oral diseases in 2016.

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Introduction

In the long evolutionary history of human beings, carbohydrate intake has evolved from the meaning of physiological needs to the meaning of psychological needs. It has changed from providing a source of human energy to satisfying human pursuit of sweetness. Human beings love sweet tastes as a result of evolution. In today’s life, it is easy to obtain sugar. However, excessive sugar intake is strongly associated with the occurrence of dental caries.

Dental caries is a human oral disease with a long history. Archaeological evidence shows that tooth decay is an ancient disease dating far back to prehistory. In the 1960s, the World Health Organization (WHO) survey found that the prevalence of dental caries in industrialized countries is quite high, while it is generally low in developing countries. Actually, the severity of dental caries increases with the progress of industrialization. In the late 1970s, the development trend of dental caries in schoolchildren around the world was polarized. In industrialized countries, the prevalence of dental caries showed a gradual downward trend, while the prevalence of dental caries in developing countries became more and more serious. Factors related to the occurrence of dental caries are multi-layered and interlocked. Among them, the availability and accessibility of sugar-sweetened diets are one of the important factors that promote the occurrence of dental caries in children and adolescents. According to the 20192020 survey of oral health of children and adolescents aged 6 to 18 by the Ministry of Health and Welfare, the impact of hand-shaken beverages on schoolchildren’s dental caries was included for the first time. Statistics show that the average value of the decayed, extracted, and filled permanent teeth (DMFT) index of schoolchildren who drink more than 3 cups of hand-shaken beverages per day is 3.65, which is more than twice that (1.68) of schoolchildren who do not drink hand-shaken beverages. This shows that the DMFT index of schoolchildren who drink hand-shaken beverages and favor high sweetness is significantly higher than schoolchildren who do not drink or tend to use less sugar. The possible reasons are that the fructose or high fructose syrup used in hand-shaken beverages can effectively promote the growth of bacterial biofilms, and the beverage ingredients are sticky foods, which cause the sugar to stay on the surface of the teeth for a longer time, making the teeth more vulnerable to cariogenic bacteria.

In fact, the effects of excessive sugar intake are gaining increasing attention, especially considering their impact on both oral and systemic health, which means that excessive sugar intake causes not only tooth decay, but also obesity, type 2 diabetes mellitus, and cardiometabolic diseases. Excessive sugar intake-induced oral and systemic diseases also increase the needs for oral and systemic health care. Therefore, effectively reducing unnecessary sugar intake may promote oral and systemic health, which also means the reduction of future medical expenses for oral and systemic health care. While dental caries and periodontal diseases are associated with each other and with increased sugar consumption, obesity, and systemic inflammation, this reinforces the WHO’s guidance that any approach intended to prevent non-communicable diseases should target common risk factors.

This study aimed to collect statistical data on the beverage serving activities in Taiwan’s Industry and Service Census and statistical data on the dental use of health care resources of National Health Insurance (NHI) for common oral diseases, and to analyze the correlation between these two groups of data. The results can be used as a reference for planning future oral health care strategies.

Materials and methods

This study adopted the methods of the secondary data analysis. The statistical data of beverage serving activities in Taiwan’s Industry and Service Census were obtained from the website of the Directorate-General of Budget, Accounting and Statistics. Since the census is conducted every 5 years, the most recent census that has been published...
online is the 2016 census. Therefore, this study used the statistical data of 2016 for analysis. Due to the Industry and Services Census excluded street vendors, the beverage serving activities only included beverage serving activities via shops. The data included the number of beverage shops and their value of beverage production by cities and counties of Taiwan. The population data of Taiwan in the end of 2016 were obtained from the website of the Ministry of the Interior. The dental treatment records were obtained from the website of the NHI Administration. These records included the numbers of patients, the numbers of out-patient visits and their medical expenses, and disease classifications.

In addition, according to the population and beverage serving activities via shops in 2016, the value of beverage production per shop and the value of beverage consumption per person were calculated and analyzed by cities and counties. According to the population and dental patients who received NHI services in 2016, dental use indicators of NHI such as dental use rate, the mean numbers of out-patient visits per 1,000 people, and the mean medical expense NHI points per person, as well as the mean numbers of out-patient visits per patient, the mean medical expense NHI points per patient, and the mean medical expense NHI points per out-patient visit were calculated and analyzed by cities and counties based on three groups of common oral-related diseases (dental caries, diseases of pulp & periapical tissues, and gingivitis & periodontal diseases) by the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10). It should be noted that the value of one NHI point is settled quarterly, and one NHI point fluctuates around 0.8–1.2 NT dollars. The dental use rate of each oral-related diseases was calculated by dividing the number of patients of each oral-related diseases to the total population.

Furthermore, the data of New Taipei City and Taipei City were combined into a group of Greater Taipei in this study as people in both cities share a common living environment. Then, the coefficient of correlation was used for comparisons between the beverage serving activities and the dental use indicators of NHI. This study did not include Kinmen County and Lienchiang County, so the cities and counties of the whole area of Taiwan were divided into 19 groups for Pearson’s correlation and regression analysis.

**Results**

**The beverage serving activities and beverage consumption in Taiwan in 2016**

The number of beverage shops and the total value of beverage production by cities and counties of Taiwan in 2016 are shown in Table 1. In Taiwan, the total value of production of beverages via shops was 85.57 billion NT dollars in 2016. Meanwhile, there were a total number of 22,472 beverage shops and a total population of 23.39 million people. Therefore, there were an average value of beverage production per shop of 3.81 million NT dollars and an average value of beverage consumption per person of 3658 NT dollars (Table 1). Taipei City was the city with the largest value of production of beverages (23.02 billion, 26.90% of 85.57 billion), followed in a descending order by Taichung City (15.95 billion, 18.64% of 85.57 billion) and Kaohsiung City (10.98 billion, 12.83% of 85.57 billion). Penghu County was the county with the smallest value of production of beverages (0.26 billion, 0.30% of 85.57 billion) among all cities and counties in Taiwan (Table 1).

Besides, Kaohsiung City was the city with the largest number of beverage shops (3989, 17.75% of 22,472), followed in a descending order by Tainan City (3121, 13.89% of 22,472) and Taichung City (2865, 12.75% of 22,472). However, Penghu County was also the county with the smallest number of beverage shops (133, 0.59% of 22,472) among all cities and counties in Taiwan (Table 1).

Furthermore, Taipei City was the city with the largest value of beverage production per shop (8.90 million), followed in a descending order by Hsinchu County (5.73 million) and Taichung City (5.57 million). The group of Greater Taipei also had a very high value of beverage production per shop (6.41 million). However, Taitung County was the county with the smallest value of beverage production per shop (1.74 million) among all cities and counties in Taiwan (Table 1).

In addition, Taipei City was the city with the largest value of beverage consumption per person (8538 NT dollars), followed in a descending order by Taichung City (5764 NT dollars) and Chiayi City (4262 NT dollars). The group of Greater Taipei also had a very high value of beverage consumption per person (4535 NT dollars). However, Miaoli County was the county with the smallest value of beverage consumption per person (1467 NT dollars) among all cities and counties in Taiwan (Table 1). These results indicate that southern cities have a larger number of beverage shops, while northern and central cities have higher amounts of beverage production and consumption. However, in the eastern region and the outlying islands, both the number of beverage shops and the amounts of beverage production and consumption are relatively low (Table 1).

**The dental use indicators of National Health Insurance for common oral-related diseases in Taiwan in 2016**

The dental use indicators of NHI for three groups of common oral-related diseases (dental caries, diseases of pulp & periapical tissues, and gingivitis & periodontal diseases) by cities and counties of Taiwan in 2016 are shown in Tables 2-4. For dental caries, the number of patients, the number of out-patient visits, and the medical expenses were 6.33 million patients, 12.84 million visits, and 16.03 billion NHI points, respectively, in 2016. Moreover, based on the corresponding value per person, the dental use rate, the number of out-patient visits per 1,000 people, and the medical expenses per person were 27.05%, 550 visits, and 685 NHI points, respectively. Meanwhile, based on the corresponding value per patient, the number of out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit were 2.03 visits, 2534 NHI points, and 1248 NHI points, respectively (Table 2).

For diseases of pulp & periapical tissues, the number of patients, the number of out-patient visits, and the medical expenses were 1.84 million patients, 3.40 million visits, and 5.80 billion NHI points, respectively, in 2016. Based on the corresponding value per person, the dental use rate, the number of out-patient visits per 1,000 people, and the
medical expenses per person were 7.88%, 145 visits, and 248 NHI points, respectively. Meanwhile, based on the corresponding value per patient, the number of out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit were 1.84 visits, 3146 NHI points, and 1706 NHI points, respectively (Table 3).

For gingivitis & periodontal diseases, the number of patients, the number of out-patient visits, and the medical expenses were 8.34 million patients, 15.87 million visits, and 13.83 billion NHI points, respectively, in 2016. Based on the corresponding value per person, the dental use rate, the number of out-patient visits per 1,000 people, and the medical expenses per person were 35.65%, 679 visits, and 591 NHI points, respectively. Meanwhile, based on the corresponding value per patient, the number of out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit were 1.90 visits, 1658 NHI points, and 871 NHI points, respectively (Table 4).

Among three groups of common oral-related diseases, gingivitis & periodontal diseases had the highest values in the number of patients (8.34 million patients), the number of out-patient visits (15.87 million visits), the dental use rate (35.65%), and the number of out-patient visits per patient (1.90 visits), followed in a descending order by dental caries (6.33 million patients, 12.84 million visits, 27.05%, and 145 visits, respectively) and diseases of pulp & periapical tissues (1.84 million patients, 3.40 million visits, 7.88%, and 145 visits, respectively) (Tables 2-4).

Dental caries had the highest values in medical expenses (16.03 billion NHI points), the medical expenses per person (685 NHI points), and the number of out-patient visits per patient (2.03 visits), followed in a descending order by gingivitis & periodontal diseases (13.83 billion NHI points, 591 NHI points, and 1.90 visits, respectively) and diseases of pulp & periapical tissues (5.80 billion NHI points, 248 NHI points, and 1.84 visits, respectively) (Tables 2-4).

Moreover, diseases of pulp & periapical tissues had the highest values in medical expenses per patient (3146 NHI points) and the medical expenses per out-patient visit (1706 NHI points), followed in a descending order by dental caries (2534 and 1248 NHI points, respectively) and gingivitis & periodontal diseases (1658 and 871 NHI points, respectively) (Tables 2-4). These results indicate that among three common oral-related diseases, dental caries consumes more medical expenses, and patients with dental caries also have higher average number of dental visits. The number of patients with gingivitis and periodontal diseases is the largest among the three groups of patients, and the total number of dental visits is also the largest among the three, which reflects a higher dental use rate. Although the number of patients, the number of dental visits, and the medical expenses consumed by diseases of pulp and periapical tissues are lower, the average medical expenses per patient or per dental visits are higher (Table 3).

Comparison of various dental use indicators by cities and counties, New Taipei City had the highest values in the number of patients, the number of out-patient visits, and the medical expenses for three groups of common oral-related diseases, while Penghu County had the lowest corresponding values (Tables 2-4). This was all about the size of the population. For dental caries, Penghu County had the highest values in the number of patients, the number of out-patient visits, and the medical expenses, while New Taipei City had the lowest values (Tables 2-4).
had the highest values in dental use rate (31.45%), the number of out-patient visits per 1,000 people (708 visits), the medical expenses per person (275 NHI points), the number of out-patient visits per patient (2.25 visits), and the medical expenses per patient (1244 NHI points). Moreover, Taoyuan City had the highest value in medical expenses per person (275 NHI points). Hualien County had the highest values in dental use rate (9.02%) and the medical expenses per person (1734 NHI points). Penghu County had the highest value in the number of out-patient visits per 1,000 people (980 visits). Kaohsiung City had the highest values in the number of out-patient visits per patient (2.09 visits). Furthermore, Miaoli County had the highest values in medical expenses per person (1734 NHI points) and the medical expenses per out-patient visit (956 NHI points) (Table 4). These results indicate that based on the dental use per population or per patient as an indicator, a city or a county with a large population may not necessarily have a high dental use rate.

The coefficient of correlation between the beverage serving activities and the dental use indicators of National Health Insurance for common oral-related diseases in Taiwan in 2016

The coefficient of correlation (Pearson’s r) between the beverage serving activities and the dental use indicators of NHI for three groups of common oral-related diseases (dental caries, diseases of pulp & periapical tissues, and gingivitis & periodontal diseases) in Taiwan in 2016 are shown in Table 5. Among the three groups of common oral-related diseases, the total value of beverage production had a very high positive correlation with the number of patients, the number of out-patient visits, and the medical expenses, for all three groups of common oral-related diseases, and all Pearson’s r values were 0.96–0.97 (Table 5).

In addition, the number of beverage shops also had a very high positive correlation with the number of patients, the number of out-patient visits, and the medical expenses, and their Pearson’s r values were 0.89–0.92. Furthermore, the value of beverage production per shop also had a very high positive correlation with the same dental use indicators, and their Pearson’s r values were 0.66–0.68 (Table 5). Because a city or a county with more population will inevitably respond to more beverage serving activities (such as the total value of beverage production, the number of beverage shops, and the value of beverage production per shop) and high dental use indicators (such as the number of patients, the number of out-patient visits, and the medical expenses), it is also inevitable that the above parameters are highly positively correlated (Table 5).

### Table 2: The dental use indicators of National Health Insurance for dental caries by cities and counties of Taiwan in 2016.

| City                | Number of patients | Number of out-patient visits | Medical expenses (1,000 NHI points) | Dental use rate (%) | Number of out-patient visits per 1,000 people | Medical expenses per person (NHI points) | Number of out-patient visits per patient | Medical expenses per patient (NHI points) | Medical expenses per out-patient visit (NHI points) |
|---------------------|--------------------|------------------------------|-------------------------------------|---------------------|-----------------------------------------------|----------------------------------------|------------------------------------------|--------------------------------------------|---------------------------------------------------|
| New Taipei City    | 1,076,893          | 2,173,330                    | 2,645,740                           | 27.06               | 546                                           | 665                                    | 2.02                                     | 2457                                        | 1217                                              |
| Taipei City        | 799,346            | 1,630,980                    | 1,924,538                           | 29.65               | 605                                           | 714                                    | 2.04                                     | 2408                                        | 1180                                              |
| (Greater Taipei)   | (1,876,239)        | (3,804,310)                  | (4,570,278)                         | (28.11)             | (570)                                         | (685)                                  | (2.03)                                   | (2436)                                      | (1201)                                             |
| Taoyuan City       | 562,077            | 1,131,482                    | 1,485,365                           | 26.17               | 527                                           | 692                                    | 2.01                                     | 2643                                        | 1313                                              |
| Taichung City      | 809,045            | 1,795,967                    | 2,039,276                           | 29.24               | 577                                           | 737                                    | 1.97                                     | 2521                                        | 1278                                              |
| Tainan City        | 518,042            | 1,106,038                    | 1,390,527                           | 27.47               | 586                                           | 737                                    | 2.14                                     | 2684                                        | 1257                                              |
| Kaohsiung City     | 785,145            | 1,638,589                    | 2,115,333                           | 28.25               | 590                                           | 761                                    | 2.09                                     | 2694                                        | 1291                                              |
| Ilan County        | 110,496            | 220,554                      | 257,618                             | 24.15               | 482                                           | 563                                    | 2.00                                     | 2331                                        | 1168                                              |
| Hsinchu County     | 142,536            | 286,067                      | 358,636                             | 26.03               | 523                                           | 655                                    | 2.01                                     | 2516                                        | 1254                                              |
| Miaoli County      | 135,698            | 274,105                      | 350,937                             | 24.27               | 490                                           | 628                                    | 2.02                                     | 2586                                        | 1280                                              |
| Changhua County    | 341,722            | 669,396                      | 834,717                             | 26.55               | 520                                           | 649                                    | 1.96                                     | 2443                                        | 1247                                              |
| Nantou County      | 125,714            | 242,568                      | 307,431                             | 24.89               | 480                                           | 609                                    | 1.93                                     | 2445                                        | 1267                                              |
| Yunlin County      | 154,814            | 307,997                      | 388,255                             | 22.28               | 443                                           | 559                                    | 1.99                                     | 2508                                        | 1261                                              |
| Chiayi County      | 121,266            | 240,369                      | 299,345                             | 23.53               | 466                                           | 581                                    | 1.98                                     | 2469                                        | 1245                                              |
| Pingtung County    | 173,713            | 350,243                      | 447,078                             | 20.78               | 419                                           | 535                                    | 2.02                                     | 2574                                        | 1276                                              |
| Taitung County     | 48,110             | 95,758                       | 118,599                             | 21.79               | 434                                           | 537                                    | 1.99                                     | 2465                                        | 1239                                              |
| Hualien County     | 86,201             | 186,082                      | 223,278                             | 26.05               | 562                                           | 675                                    | 2.16                                     | 2590                                        | 1200                                              |
| Penghu County      | 32,472             | 73,105                       | 90,951                              | 31.45               | 708                                           | 881                                    | 2.25                                     | 2801                                        | 1244                                              |
| Keelung City       | 93,871             | 190,608                      | 219,955                             | 25.23               | 512                                           | 591                                    | 2.03                                     | 2343                                        | 1154                                              |
| Hsinchu City       | 130,580            | 271,341                      | 334,015                             | 29.86               | 620                                           | 764                                    | 2.08                                     | 2558                                        | 1231                                              |
| Chiayi City        | 79,347             | 159,824                      | 198,232                             | 29.40               | 592                                           | 735                                    | 2.01                                     | 2498                                        | 1240                                              |
| Overall            | 6,327,088          | 12,844,403                   | 16,029,826                          | 27.05               | 550                                           | 685                                    | 2.03                                     | 2534                                        | 1248                                              |
Therefore, we also used the value of beverage consumption per person and the dental use per person as indicators (such as the dental use rate, the number of out-patient visits per 1,000 people, and the medical expenses per person) to analyze their correlation. The results showed that there was a high positive correlation between the value of beverage consumption per person and the dental use indicators (the number of patients, the number of out-patient visits, and the medical expenses) for all three groups of common oral-related diseases, of which their Pearson’s r values were 0.55 to 0.59 (Table 5).

In addition, the value of beverage consumption per person also had a high positive correlation with the dental use rate, the number of out-patient visits per 1,000 people, and the medical expenses per person for dental caries and for gingivitis & periodontal diseases, and their Pearson’s r values were 0.52 to 0.65 (Table 5).

For diseases of pulp & periapical tissues, however, the above parameters also showed at least a moderate positive correlation, and their Pearson’s r values were 0.18 to 0.40 (Table 5). For gingivitis & periodontal diseases, the total value of beverage production and the number of beverage shops also had a high positive correlation with the above parameters, and their Pearson’s r values were 0.44 to 0.51 (Table 5). This result indicates that the higher the beverage consumption per capita, the higher the dental use per capita.

### Discussion

In Taiwan, the market for hand-shaken beverages is huge, and there are a lot of hand-shaken beverage shops. This indicates the fact that many Taiwanese like to drink hand-shaken beverages. Taiwan has now become a beverage kingdom, and beverage manufacturers from Taiwan can be found all over the world. Since the early 1980s, Taiwan’s economy has grown rapidly, and bubble tea has evolved into an explosively growing takeaway hand-shaken beverage. The invention of pearl milk tea has brought about an innovation in the taste of beverages. In Taiwan, “drinking hand-shaken beverages” has long become a life culture that meets psychological needs. However, due to most hand-shaken beverages containing a lot of sugar and energy, drinking too much hand-shaken beverages does not seem to be very healthy, especially for those containing too much sugar which may cause dental caries. To the best of our knowledge, this study is the first one focusing on the correlation between the beverage serving activities and the dental use of health care resources of NHI in Taiwan. This may be the first study of dental public health focusing on the relationship between beverage consumption and common oral diseases such as dental caries, diseases of pulp & periapical tissues, and gingivitis & periodontal diseases.

By government regulations, the beverage serving activities refer to shops and vendors engaged in preparing

| Table 3 | The dental use indicators of National Health Insurance for diseases of pulp & periapical tissues by cities and counties of Taiwan in 2016. |
|---------|----------------------------------------------------------------------------------------------------------------------------------|
| Number of patients | Number of out-patient visits | Medical expenses (1,000 NHI points) | Dental use rate (%) | Number of out-patient visits per 1,000 people | Medical expenses per person (NHI points) | Number of out-patient visits per patient | Medical expenses per patient (NHI points) | Medical expenses per out-patient visit (NHI points) |
| New Taipei City | 327,111 | 622,223 | 1,049,877 | 8.22 | 156 | 264 | 1.90 | 3210 | 1687 |
| Taipei City (Greater Taipei) | 546,803 | (1,057,610) | (1,755,739) | (8.19) | (158) | (263) | (1.93) | (3211) | (1660) |
| Taoyuan City | 159,508 | 291,518 | 510,024 | 7.43 | 136 | 237 | 1.83 | 3197 | 1750 |
| Taichung City | 230,293 | 394,935 | 724,489 | 8.32 | 143 | 262 | 1.71 | 3146 | 1834 |
| Tainan City | 153,105 | 288,713 | 501,032 | 8.12 | 153 | 266 | 1.89 | 3272 | 1735 |
| Kaohsiung City | 209,406 | 385,436 | 657,923 | 7.53 | 139 | 237 | 1.84 | 3142 | 1707 |
| Ilan County | 36,208 | 68,675 | 105,333 | 7.91 | 150 | 230 | 1.90 | 2909 | 1534 |
| Hsinchu County | 37,732 | 68,250 | 125,436 | 6.89 | 125 | 229 | 1.81 | 3324 | 1838 |
| Miaoli County | 41,481 | 70,896 | 125,672 | 7.42 | 127 | 225 | 1.71 | 3030 | 1773 |
| Changhua County | 103,143 | 180,535 | 304,211 | 8.01 | 140 | 236 | 1.75 | 2949 | 1685 |
| Nantou County | 41,059 | 71,692 | 125,299 | 8.13 | 142 | 248 | 1.75 | 3052 | 1748 |
| Yunlin County | 49,205 | 88,484 | 149,543 | 7.08 | 127 | 215 | 1.80 | 3039 | 1690 |
| Chiayi County | 40,076 | 71,793 | 125,765 | 7.78 | 139 | 244 | 1.79 | 3138 | 1752 |
| Pingtung County | 55,429 | 98,372 | 158,418 | 6.63 | 118 | 190 | 1.77 | 2858 | 1610 |
| Taitung County | 14,894 | 27,172 | 42,818 | 6.75 | 123 | 194 | 1.82 | 2875 | 1576 |
| Hualien County | 28,667 | 57,536 | 90,005 | 8.66 | 174 | 272 | 2.01 | 3140 | 1564 |
| Penghu County | 9,312 | 16,766 | 28,443 | 9.02 | 162 | 275 | 1.80 | 3054 | 1696 |
| Keelung County | 29,768 | 56,598 | 86,437 | 8.00 | 152 | 232 | 1.90 | 2904 | 1527 |
| Hsinchu City | 34,809 | 64,631 | 112,371 | 7.96 | 148 | 257 | 1.86 | 3228 | 1739 |
| Chiayi City | 21,517 | 38,717 | 67,991 | 7.97 | 143 | 252 | 1.80 | 3160 | 1756 |
| Overall | 1,842,415 | 3,398,329 | 5,796,948 | 7.88 | 145 | 248 | 1.84 | 3146 | 1706 |
Our study also showed a similar result, but in terms of beverage consumption per person, a higher consumption was shown in the central region of Taiwan. Furthermore, according to the statistics of the Ministry of Economic Affairs, the total production of beverages via shops increased from 93.88 billion NT dollars in 2017 to a recent highest point of 99.42 billion NT dollars in 2019, and then decreased to 97.83 billion NT dollars in 2020. Due to the global outbreak of COVID-19, the total production of beverages dropped in 2020, and this was the first decline in recent years. On the other hand, according to the statistics of the NHI Administration, the total medical expenses for dental out-patient clinics increased from 404.0 billion NHI points in 2016 to 457.5 billion NHI points in 2020. It indicates that the dental health care cost does not decrease due to the COVID-19 pandemic. However, the medical expenses for dental caries and diseases of pulp & periapical tissues showed the same trend as the total production of beverages. The medical expenses for dental caries and diseases of pulp & periapical tissues increased from 161.3 to 58.4 billion NHI points in 2016 to 163.0 and 66.0 billion NHI points in 2019, and then decreased to 159.5 and 65.7 billion NHI points in 2020, respectively. Conversely, the medical expenses for gingivitis & periodontal diseases showed the same trend as the total dental expenses. The medical expenses for gingivitis & periodontal diseases increased from 139.3 billion NHI points in 2016 to 173.5 billion NHI points in 2019 and further to 180.8 billion NHI points in 2020. This may be due to the fact that in recent years, the health policy tends to encourage people to receive regular scaling and early treatment of periodontal diseases. In fact, diseases of pulp & periapical tissues are the results of further deterioration of dental caries. In recent years, the expenditure of medical expenses for these two dental diseases has shown the same development trend as the total production of beverages. Therefore, this forces us not to ignore the correlations among the beverage consumption, excessive sugar intake, and dental caries-related diseases.

This study found that although diseases of pulp & periapical tissues consumed less NHI costs overall, the average

| Table 4 | The dental use indicators of National Health Insurance for gingivitis & periodontal diseases by cities and counties of Taiwan in 2016. |
|---------|---------------------------------------------------------------|
|         | Number of patients | Number of out-patient visits | Medical expenses (1,000 NHI points) | Dental use rate (%) | Number of out-patient visits per 1,000 people | Medical expenses per person (NHI points) | Number of out-patient visits per patient (NHI points) | Medical expenses per out-patient visit (NHI points) |
| New Taipei City | 1,471,139 | 2,747,209 | 2,515,869 | 36.97 | 690 | 632 | 1.87 | 1710 | 916 |
| Taipei City (Greater Taipei) | 1,132,140 (2,603,279) | 2,169,883 (4,917,092) | 1,959,099 (4,474,968) | 42.00 | 805 | 727 | 1.92 | 1730 | 903 |
| Taoyuan City | 695,769 | 1,240,901 | 1,103,964 | 32.40 | 578 | 514 | 1.78 | 1587 | 890 |
| Taichung City | 1,065,632 | 1,995,451 | 1,680,716 | 38.51 | 721 | 607 | 1.87 | 1577 | 842 |
| Tainan City | 660,311 | 1,306,113 | 1,117,338 | 35.01 | 693 | 592 | 1.98 | 1692 | 855 |
| Kaohsiung City | 1,058,754 | 2,230,384 | 1,779,657 | 38.09 | 802 | 640 | 2.11 | 1681 | 798 |
| Hsinchu County | 171,551 | 302,422 | 281,662 | 31.33 | 551 | 514 | 1.76 | 1642 | 934 |
| Miaoli County | 163,561 | 302,422 | 281,662 | 31.33 | 551 | 514 | 1.76 | 1642 | 934 |
| Changhua County | 435,505 | 802,568 | 698,245 | 33.83 | 624 | 535 | 1.84 | 1583 | 859 |
| Nantou County | 163,842 | 294,924 | 256,073 | 32.43 | 584 | 507 | 1.80 | 1563 | 868 |
| Yunlin County | 203,622 | 372,198 | 321,659 | 29.30 | 536 | 463 | 1.83 | 1589 | 864 |
| Chiayi County | 156,175 | 298,955 | 259,841 | 30.31 | 576 | 504 | 1.91 | 1664 | 869 |
| Pingtung County | 228,950 | 434,494 | 355,841 | 32.79 | 520 | 426 | 1.90 | 1554 | 819 |
| Taitung County | 59,206 | 111,377 | 102,752 | 26.81 | 504 | 465 | 1.88 | 1735 | 923 |
| Hualien County | 105,296 | 203,136 | 183,353 | 31.82 | 614 | 554 | 1.93 | 1741 | 903 |
| Penghu County | 42,996 | 90,908 | 73,968 | 41.64 | 880 | 716 | 2.11 | 1720 | 814 |
| Keelung City | 126,406 | 234,548 | 206,302 | 33.97 | 600 | 554 | 1.86 | 1632 | 880 |
| Hsinchu City | 160,164 | 297,582 | 271,468 | 36.62 | 680 | 621 | 1.86 | 1695 | 912 |
| Chiayi County | 100,685 | 194,755 | 175,316 | 37.31 | 722 | 650 | 1.93 | 1741 | 900 |
| Overall | 8,339,379 | 15,872,306 | 13,830,613 | 35.65 | 679 | 591 | 1.90 | 1658 | 871 |
NHI costs per patient were higher, which means that the sequelae of dental caries in patients may in turn cause more medical expenses. Moreover, the self-payment for further prosthesis fabrication after endodontic treatment may cause the financial burden of the patients themselves or their families. This also highlights the importance of preventing dental caries and avoiding the deterioration of dental caries in the early stage. In addition to correcting adverse oral health behavior, reducing the excessive sugar intake is also a key factor to reduce dental caries and diseases of pulp & periapical tissues.

A 2019-2020 survey of Taiwan shows that the mean DMFT of schoolchildren who drink more than 3 cups of hand-shaken beverages per day is 3.65, which is significantly higher than that (1.68) of schoolchildren who do not drink. Moreover, the average decayed teeth (DT) and filled permanent teeth (FT) also show the same trend. In terms of sweetness hobby of hand-shaken beverages, it is more related to DT, showing that the mean DT of schoolchildren who like to drink beverages with high sugar is 1.00, which is significantly higher than that (0.71) of schoolchildren who like sugar-free beverages. In Taiwan, sugar-sweetened beverages are currently banned in middle schools and elementary schools. Only seven types of beverages, including 100% vegetable juice, fresh milk, long-lasting milk, soy milk, yogurt, packaged drinking water, and mineral water, can be sold in middle schools and elementary schools, and the sugar content is limited. Despite this,
scholars are still concerned that there are many hand-shaken beverage shops outside campuses. The production of beverages and the number of beverage shops have continued to grow in recent years. Such convenience for hand-shaken beverages may cause a negative impact on the oral health of our schoolchildren. Furthermore, scholars speculate that there are two main reasons for the cariogenicity of hand-shaken beverages. The sugar in hand-shaken beverages is mostly fructose or high fructose syrup. Strep. mutans in the high fructose syrup environment can produce acid and reduce the pH value, and the rate of decline is much faster than in the sucrose environment. This indicates that sugar can effectively produce acidity and promote the growth of biofilms, leading to the occurrence of dental caries. Many ingredients in hand-shaken beverages are sticky foods with high starch content, which may cause sugar to remain on the surface of the teeth for a longer time, and then in turn make the teeth more vulnerable to cariogenic bacteria.

From a macroscopic viewpoint, the factors related to the occurrence of dental caries are multi-layered and interlocked, including individual congenital factors and oral health care behavior, family socioeconomic status, school support and supervision, individual habits for sugar-sweetened diets, the convenience of obtaining sugar-sweetened foods in life, the availability and accessibility of dental care resources, and the emphasis and implementation of national oral health policies. From a microscopic viewpoint, however, there is no doubt that excessive sugar consumption is the main cause of dental caries. However, it should be noted that the dental use rate in this study refers to the proportion of the number of patients with oral-related diseases who receive dental services from NHI to the population, but the actual number of patients with oral-related diseases should account for a higher proportion of the population. This is because there may be some patients with low oral health awareness, low socioeconomic status or other disadvantaged status who do not seek for dental health care. The possible factors and effects of this phenomenon still need further studies.

The results of this study showed a positive correlation between hand-shaken beverage consumption and the dental use of health care resources of NHI for common oral diseases. In particular, there was a high positive correlation between hand-shaken beverage consumption and the medical expenses for dental caries and gingivitis & periodontal diseases. This study was not intended to demonstrate a causal relationship between high hand-shaken beverage consumption and high dental use of health care resources of NHI for common oral diseases. However, it is undeniable that the high hand-shaken beverage consumption may lead to excessive sugar intake, which is the main cause of dental caries. According to the comparison of past studies, although the dental caries status of adult and schoolchildren in Taiwan has been improving year by year, the expenditure of medical expenses for dental caries-related diseases is still increasing year by year, except for the decrease in 2020 due to the COVID-19 pandemic. It is well known that the expenditure of medical expenses is affected by multiple factors. In addition to the incidence of the disease, the relevant factors also include the severity of the diseases, the patients’ medical awareness and behavior, medical waste behavior, and the regulations of the health insurance system. In any case, reducing sugar intake and improving oral health behavior are correct and should be advocated.

Dental caries is highly prevalent and has negative impacts on societies and the quality of life of individuals at all stages. Excessive sugar consumption and low socioeconomic status are associated with increased chronic oral disease burden values, especially dental caries. Furthermore, the sugar consumption is associated with other non-communicable conditions and diseases, such as obesity, diabetes, and cardiovascular diseases. However, dental caries-related diseases are highly preventable, but require interventions which can lead to reduction of their primary causes such as the excessive sugar intake in the diet. Such interventions have the potential to reduce dental caries-related diseases and other non-communicable diseases that are linked to excessive sugar consumption. Future surveys should monitor the long-term impact of different health policies, in order to assess the actual results in reducing sugar consumption. Furthermore, evaluation of health policies should not only be restricted to the assessment of reducing sugar consumption, but also monitor the impact on clinically relevant outcomes such as dental caries-related diseases and other non-communicable diseases.

In addition to maintaining oral health, reducing or avoiding unnecessary excessive sugar intake also has the effect of ruling out primary causes of other non-communicable conditions and diseases. Furthermore, in addition to the correct tooth-cleaning method, the concept of proper sugar intake should also be emphasized in oral health education. Therefore, from a cost-effectiveness viewpoint and a long-term benefit for oral health and systemic health, Taiwan government should develop a better oral health care policy including a health education strategy of appropriate sugar intake to prevent dental caries and other non-communicable diseases in Taiwanese people.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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References

1. He XS, Zhou XD, Shi WY. Oral microbiology: past, present and future. Int J Oral Sci 2009;1:47–58.
2. Greene JC. Indicators for oral health and their implications for industrialized nations. Int Dent J 1983;33:67–72.
3. Ministry of Health and Welfare. *The 2019-2020 survey of oral health of children and adolescents aged 6 to 18*. Taipei, Taiwan: Ministry of Health and Welfare, 2020 [In Chinese].

4. Friuli S, Colombo S, De Giorgio S, Paglia M. Added sugar intake: Carious disease in children and systemic implications in adults. *Ital J Dent Med* 2020;5:1–7.

5. Carmo CDS, Ribeiro MRC, Teixeira JXP, et al. Added sugar consumption and chronic oral disease burden among adolescents in Brazil. *J Dent Res* 2018;97:508–14.

6. Chen PJ. *An exploring of Taiwan’s handmade drinks shop*. Master thesis. Yunlin: National Yunlin University of Science and Technology, 2017 [In Chinese, English abstract].

7. Li BX. *The study of relationship among consumer perception, intention and satisfaction in hand-held drink shop*. Master thesis. Taoyuan: Vanung University, 2020 [In Chinese].

8. Feldens CA, Pinheiro LL, Cury JA, et al. Added sugar and oral health: a position paper of the Brazilian Academy of Dentistry. *Frontiers in Oral Health* 2022;3:1–7.

9. Cheng FC, Chiang CP. Analysis of emergency dental visits of pediatric patients in the National Health Insurance of Taiwan in 2020. *J Dent Sci* 2022;17:942–50.

10. Cheng FC, Chiang CP. The dental use by pediatric patients in the National Health Insurance of Taiwan in 2020. *J Dent Sci* 2022;17:951–7.

11. Health Promotion Administration. *Oral health status survey of children under 6 years old in Taiwan, 2011*. Taipei, Taiwan: Health Promotion Administration, 2013 [In Chinese].

12. Ministry of Health and Welfare. *Oral health status survey of children under 6 years old in Taiwan, 2018*. Taipei, Taiwan: Ministry of Health and Welfare, 2019 [In Chinese].