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Estimating Disability-Free Life Expectancy of Malaysian Population Using the Sullivan's Approach

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ABSTRACT

As we age, the chances of becoming disabled tend to increase due to an accumulation of health risks from a lifetime of illness, injury, and disability. This research examines the increasing life expectancy of the Malaysian population in relation to their disability status from 2015 to 2019. Disability-free life expectancy (DFLE) was computed using the Sullivan's approach; subsequently, compression or expansion of disability over the two observation years, 2015 and 2019, were analysed. Malaysian disability prevalence rates by age groups for 2015 and 2019 were used to execute this research. In addition, the respective mortality rates by age were gathered from the Department of Statistics of Malaysia. Results showed that, as life expectancy increases, the number of years lived without a disability would rise significantly while the anticipated number of years with a disability will be concurrently declining, suggesting evidence of disability compression. It was also observed that the median age at which the number of years spent with a disability higher than without a disability was 55 in 2015, then delayed to 67.5 in 2019. This study informs medical practitioners and health policymakers about the average lifespan of Malaysians without disabilities, which can indicate the population's general health status.

Keywords: Disability, disability-free life expectancy, life table, morbidity, Sullivan's method

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INTRODUCTION

Malaysia is moving towards an ageing nation as the percentage of older people aged sixty and above increased tremendously over the last four decades. One of the elderly population's concerns is that they tend to become disabled due to an accumulation of health problems. They face some obstacles in performing daily routines, limiting their full capabilities, thus requiring dependability from family members to perform their daily activities (ADLs) (Prina et al., 2020).

Statistics showed that the life expectancy of the Malaysian population has been increasing remarkably over the years, from 53.52 in 1950 to 76.51 in 2021 (Macrotrends.net, 2023). Despite the COVID-19 outbreak that emerged at the end of 2019, the Malaysian population's life expectancy at birth has continued to rise. (Ministry of Economy, 2021). The increase in life expectancy raises the important question of whether the population lives longer in good or poor health. According to Moreno et al. (2020), changes in lifestyle and medical technology have contributed to the increase in life expectancy of the population and, at the same time, delayed the onset of chronic illness and disability, leading to a compression of morbidity at older ages. On the other hand, the increase in life expectancy at older ages also expands morbidity as this group of people is likely to associate with ageing-related diseases commonly experienced by the elderly (Jagger et al., 2014). These two theories can be absolute and relative, whereby the increase in life expectancy can be with or without disability (Moreno et al., 2020). An in-depth study on assessing and analysing the life expectancy with and without a disability is crucial in planning for social and health policies, particularly related to the elderly.

The Healthy Life Expectancy (HLE) theory addresses how many years of life were spent in good rather than poor health. HLE measures population health by integrating mortality and morbidity levels of a population and partitions years of life lived at a particular age into healthy and unhealthy years. The disability-free life expectancy (DFLE) is one measure of HLE, which indicates the remaining years of life spent in an able state and can perform daily activities independently without assistance from the carers (Moreno et al., 2018). Existing research on HLE and DFLE of various populations and periods has often reached inconsistent conclusions about the competing nature of mortality and morbidity. In Brazil, for instance, the proportion of healthy years lost increases significantly with age due to long-term disease or disability that limits daily activities, regardless of the difficulty and severity of the functional limitations (Romero et al., 2005). In Japan, the gains before 1995 were in years of good health, while the gains in life expectancy after 1995 were in poor health (Yong & Saito, 2009). Moreover, Belgian women had a DFLE at birth of 66.6 years out of a total life expectancy of 81.4 years, leading to 82% of their lifespan free of disability (Stiefel et al., 2010).

The computation of the person-years lived in the health state requires longitudinal data to estimate the probability of transitioning from healthy to poorer health or death. The subject of interest may frequently enter and leave states repeatedly, in which this dynamic can only be captured through a long-term follow-up study (Dudel & Myrskylä, 2020). Even though longitudinal data can be used to evaluate healthy life expectancy using the Markov model, access to this data is generally limited and inaccessible. As a result, the Sullivan method serves as an alternative strategy that allows for readily available secondary data. According to Jagger et al. (2007), both approaches yield comparable outcomes if all rates are smooth over time. The Sullivan method is an advantage as it can generally be used for its simplicity, relative accuracy and ease of interpretation. Sullivan's method explored the association between mortality and morbidity or disability in a single summary measure of a population's health status (Jagger et al., 2007). It has been used extensively to estimate the DFLE in various populations at the national level. This method remains the most widely used method among researchers and government officials for estimating DFLE. See, for example, Imai and Soneji (2012), Brønnum-Hansen et al. (2017) and Minagawa and Saito (2018). Sullivan's method mainly combines the period life table, the primary method to calculate life expectancy, with the age-specific disability prevalence obtained from cross-sectional national survey data. In particular, the method divides the total number of person-years lived, generated from the period life table, into the expected life expectancy with and without disabilities depending on the fraction of people with disabilities.

In Malaysia, the application of Sullivan's method has been extended for cancer patients to estimate cancer-free life expectancy (Omar et al., 2019). In addition, a study from Mathers et al. (2000) estimated DFLE for Malaysian aged 81 to 96 years old. However, the analyses were based on data year 1999 which is outdated and does not represent Malaysia's current perspective on disability. Up to today, the study on the trends of disability experience for Malaysian population is still lacking.

Therefore, this research aims to estimate disability-free life expectancy for the Malaysian population using the Sullivan’s approach and extends the analysis starting from 18 years old and above, using recent NHMS survey datasets for year 2015 and 2019. The results of DFLE in two respective years are compared, and the compression of disability is further analysed. The trends of disability between the two years provide valuable insights into the disability burden, prevalence, and overall health status of Malaysian population.

MATERIALS AND METHODS

In order to estimate disability-free life expectancy for the Malaysian population, this research adopts the Sullivan’s method, which requires two types of secondary data, including age-specific disability prevalence rates and age-specific mortality rates.

Data Collection

Disability prevalence rates according to age were obtained from the National Institute of Health (2019) report. The NHMS survey was conducted by the Malaysia Institute of Public Health once every four years. The survey, specifically on disability, was available only in 2015 and 2019. The disability prevalence estimates by age group for 2019 were obtained directly from the National Health & Morbidity Survey report (National Institute of Health, 2019). The sample included people aged 18 and older and were national representatives. The disability prevalence rates by age group for 2015 were retrieved from (Ahmad et al., 2017), as data by age group were not available directly in the NHMS (2015) report. Ahmad et al. (2017) surveyed the NHMS disability module in 2015, including people aged 18 and above and published the disability prevalence data by age group. The questionnaires were based on the International Classification of Functioning, Disability and Health (ICF) framework by the Washington Group on Disability Statistics (WG). Participants were classified as without disability or with a disability according to the following questions:

"Do you have difficulty in hearing, even if using a hearing aid?"
"Do you have difficulty in walking or climbing steps?"
"Do you have difficulty in remembering or concentrating?"
"Do you have difficulty with self-care such as washing all over or dressing?"
"Using your usual (customary) language, do you have difficulty in communicating?"

The response categories:(1) No, no difficulty, (2) Yes, some difficulty, (3) Yes, many difficulties and (4) Cannot do it at all. The most important quantity for calculating DFLE is the person-years lived in each age group. Several deaths of the population are required. Thus, age and gender-specific central mortality rates for the Malaysian population in 2015 and 2019 were obtained from the Department of Statistics Malaysia (DOSM). The mortality data were in the quinquennial age range from 0, 1–4, 5–9……..,75–79 and 80+.

Table 1
Age-specific disability prevalence rate among adults in Malaysia for 2015

Age	Prevalence (%)
18–30	4.21
31–40	5.31
41–50	10.07
51–60	19.24
61 & above	41

Source. Ahmad et al. (2017)

Table 2
The age-specific disability prevalence rate among adults in Malaysia for 2019

Age	Prevalence (%)
18–29	3.5
30–39	4.7
40–49	8.6
50–59	15.6
60–69	25.7
70–79	45.7
80 & above	78.4

Source. NHMS (2019)

The disability prevalence rates for 2015 and 2019 in Tables 1 and 2 were inconsistent in terms of age group range. Thus, these disability prevalence and mortality data were transformed into single-age data using the interpolation technique.

Estimation of Life Expectancy Using the Life Table Approach

The life table measures the expectation of life using the estimates of age-specific mortality rates representing a notional population, typically per 100,000 people (Imai & Soneji, 2012). A period life table is developed based on the following stationarity assumptions of the population (Imai & Soneji, 2012): (1) The age-specific mortality rate is constant throughout a year, (2) the birth rate is constant over time and, (3) the net migration rates are zero at all ages. The assumptions also imply that the number of survivors is constant over time. Therefore, the total size of the hypothetical cohort is assumed to remain constant over time.

Using the collected age-specific central mortality rates data, ${}_nm_x$, the period life table is developed following Equations 1 to 6:

Number of survivors at age x:	l_x	(1)
Probability of dying between age x and $x + n$:	${}_nq_x$	(2)
Number of deaths between ages x and $x + n$:	${}_nd_x = l_x \times {}_nq_x$	(3)
Number of person-years lived between x and $x + n$:	${}_nL_x = \frac{{}_nd_x}{{}_nm_x}$	(4)
Total number of person-years lived after age x:	$T_x = \sum {}_nL_x$	(5)
Life expectancy at age x:	$e_x = \frac{T_x}{L_x}$	(6)

Estimation of Disability-Free Life Expectancy (DFLE) Using Sullivan's Method

Unlike life expectancy, DFLE cannot be calculated only from a period life table without additional data on the prevalence of disabilities. Sullivan's method estimates DFLE by segmenting the person-years lived into the proportion with and without disability. After developing the life table above, the disability prevalence is applied to calculate the disability-free life expectancy.

Sullivan's method relies on a period life table structure. The assumptions of Sullivan's model inherit the three stationarity assumptions of the population such that (1) The age-specific mortality rate is constant throughout a year, (2) the birth rate is constant over time, and (3) the net migration rates are zero at all ages. In addition, the age-specific disability

prevalence rate is assumed to be stationary. To estimate DFLE, first, the life expectancy for Malaysia's population needs to be calculated. Then the DFLE can be measured by applying the disability prevalence rate data in the DFLE formula. The steps in finding the DLFE are represented in Equations 7 to 11.

Disability prevalence rate for age *x*. π_x (7)

Person years lived without disability in age interval. $[1-\pi_x]\ {}_nL_x$ (8)

Total years lived without disability from age *x*. $\sum[1-\pi_x]\ {}_nL_x$ (9)

Disability-free life expectancy age *x*: $DFLE_x = \frac{1}{\ell_x}\sum_{i=x}^{\omega}[1-\pi_x]\ {}_nL_x$ (10)

The proportion of remaining life spent disability-free $\frac{DFLE_x}{e_x}$ (11)

Due to sample variation, the prevalence of disability varies considerably across all ages. The rate of mortality is also subject to random variation. Because the Sullivan health expectancy is derived from mortality and morbidity rates, this is also subject to random variations. Under the four stationarity assumptions, the variance of Sullivan's estimator is given by Equation 12:

$$\sigma_x^{DF} = \frac{1}{l_x^2}\sum_{i\in A_x}\frac{{}_{n_i}\hat{\pi}_i(1-{}_{n_i}\hat{\pi}_i)\ {}_{n_i}L_i^2}{{}_{n_i}N_i} \quad (12)$$

Where,

l_x = the proportion of survivors at age *x*

${}_{n_i}\hat{\pi}_i$ = sample fraction of the disabled survey respondents within the age interval $[i, i+n_i)$

${}_{n_i}\bar{L}_i$ = total number of person-years lived in an interval, $[i, i+n_i)$

${}_{n_i}N_i$ = total number of survey respondents in the age interval, $[i, i+n_i)$

RESULTS AND DISCUSSION

Tables 3 and 4 show the estimated Malaysian total life expectancy, the expected number of years lived with and without disability, and the proportion of life spent disability-free for 18 to 60+ years old for 2015 and 2019, respectively.

Results show that the life expectancy of persons aged 18–19 increased by 1.42 years from 55.51 to 56.93, while the life expectancy of elderlies aged 60 increased by 1.07 years from 16.97 to 18.04 over the observed period. This trend is consistent with the global pattern that life expectancy continues increasing over the years in which the lifespan of elderlies increased more substantially than younger population (Ibrahim et al., 2020; United Nations, 2019).

Table 3

Life Expectancy (e_x) and Disability-Free Life Expectancy (DFLE) and proportion of life with free disability for Malaysian population in 2015

Age	Life Expectancy e_x (DOSM[a])	Life Expectancy e_x (Estimated[b])	Expected No of Years of Life				Proportion of Life Without Disability (%)
			With Disability (DLE)		Without Disability (DFLE)		
			Years	95% CI	Years	95% CI	
18–19	56.99	55.51	19.21	(18.86, 21.14)	36.30	(35.95, 36.65)	65.40
20–24	53.59	52.14	19.10	(18.75, 21.07)	33.04	(32.70, 33.39)	63.35
25–29	48.76	47.29	18.92	(20.21, 20.90)	28.37	(29.71, 30.40)	59.40
30–34	43.96	42.45	18.72	(18.39, 19.06)	23.73	(23.39, 24.07)	55.85
35–39	39.23	37.66	18.48	(18.15, 18.81)	19.18	(18.85, 19.51)	50.87
40–44	34.62	32.97	18.18	(17.86, 18.50)	14.79	(14.47, 15.11	44.77
45–49	30.14	28.37	17.77	(17.47, 18.07)	10.60	(10.30, 10.90)	37.23
50–54	25.83	23.91	17.25	(16.97, 17.53)	6.66	(6.38, 6.93)	27.67
55–59	21.73	19.61	16.50	(16.29, 16.70)	3.11	(2.91, 3.32)	15.59
60+	18.98	16.97	16.08	(15.96,16,20)	0.89	(0.77,1.01)	5.19

Note. [a]Department of Statistics Malaysia (2019)
[b]The life expectancy is calculated using the period life table approach

Disability-free life expectancy (DFLE) results indicate a compression in disability among the Malaysian population. As life expectancy steadily rose, the prevalence of disability experienced a profound shift, i.e., with small increases in life expectancy from 2015 to 2019, there was a substantial increase in the expected number of years lived without disability. For instance, in 2015, the 18–19 years old Malaysians had a life expectancy of 55.51 years. They were expected to live for 36.30 years without disability and the remaining 19.21 years with at least one disability condition. In comparison to 2019, when the life expectancy increased to 56.93, the expected lifetime years of 18–19 years old Malaysian

without a disability increased to 44.28, while the number of years they suffered from any disability was reduced to 12.66, resulting from disability compression. The compression of disability among the Malaysian population is consistent with (Fries et al., 2011) theory of healthy ageing that emphasises improvements in preventive medicine with the untapped potential of health promotion and prevention that led to a postponement of the onset of disability at later ages, which squeezing most of the disability in life into a shorter period.

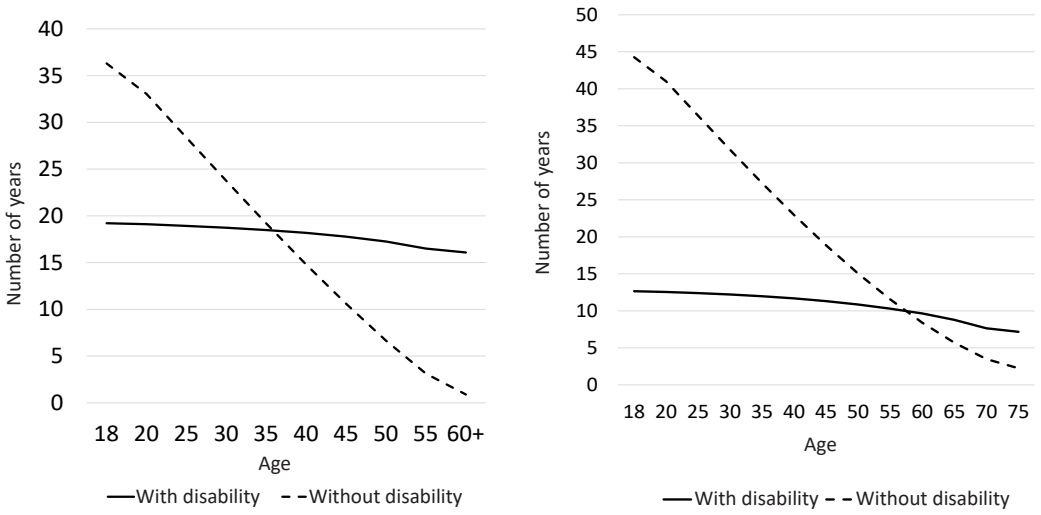
Table 4

Life Expectancy (e_x) and Disability-Free Life Expectancy (DFLE) and proportion of life with free disability for Malaysian population in 2019

Age	Life Expectancy e_x (DOSM[a])	Life Expectancy e_x (Estimated[b])	Expected No of Years of Life				Proportion of Life Without Disability (%)
			With Disability (DLE)		Without Disability (DFLE)		
			Years	95% CI	Years	95% CI	
18–19	57.00	56.93	12.66	(12.18, 13.13)	44.28	(43.80, 44.75)	77.77
20–24	53.63	53.56	12.56	(12.09, 13.02)	41.01	(40.54, 41.48)	76.55
25–29	48.82	48.75	12.40	(11.93, 13.02)	36.35	(35.89, 36.82)	74.55
30–34	44.02	43.95	12.21	(11.75, 12.68)	31.74	(31.27, 32.20)	72.19
35–39	39.29	39.22	11.98	(11.51, 12.45)	27.24	(26.77, 27.71)	69.43
40–44	34.67	34.61	11.69	(11.21, 12.16)	22.92	(22.44, 23.39)	66.19
45–49	30.21	30.14	11.31	(10.83, 11.79)	18.83	(18.36, 19.31)	62.43
50–54	25.93	25.87	10.85	(10.37, 11.33)	15.02	(14.54, 15.50)	58.00
55–59	21.89	21.84	10.30	(9.81, 10.78)	11.54	(11.05, 12.02)	52.76
60–64	18.10	18.04	9.65	(9.17, 10.14)	8.39	(7.91, 8.87)	46.39
65–69	14.53	14.48	8.79	(8.31, 9.27)	5.69	(5.21, 6.17)	39.16
70–74	11.18	11.13	7.65	(7.17, 8.13)	3.48	(3.01, 3.96)	31.09
75+	8.15	9.42	7.18	(6.64, 7.72)	2.24	(1.70, 2.78)	28.34

Note. [a]Department of Statistics Malaysia (2019)
[b]The life expectancy is calculated using the period life table approach

A similar pattern was observed for older people aged 60. Increases in life expectancy from 2015 to 2019 resulted in an increase in the expected number of years of life free from disability from 1.19 to 8.39 and reduced the expected number of years with a disability by almost half from 17.47 to 9.65. The reduction in the number of years of life with disability among Malaysian elderlies may be due to changes in medical technology that prevent chronic illnesses and the promotion of healthy ageing that emphasise a healthy lifestyle. In addition, the high costs of long-term care and limited access to public institutions force the elderly to better care for their health and well-being while trying to avoid becoming disabled.

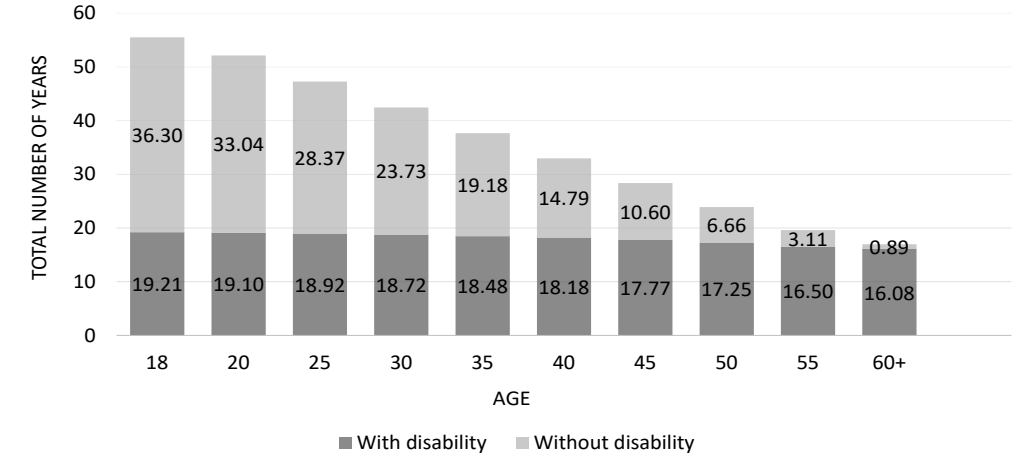


(a) (b)

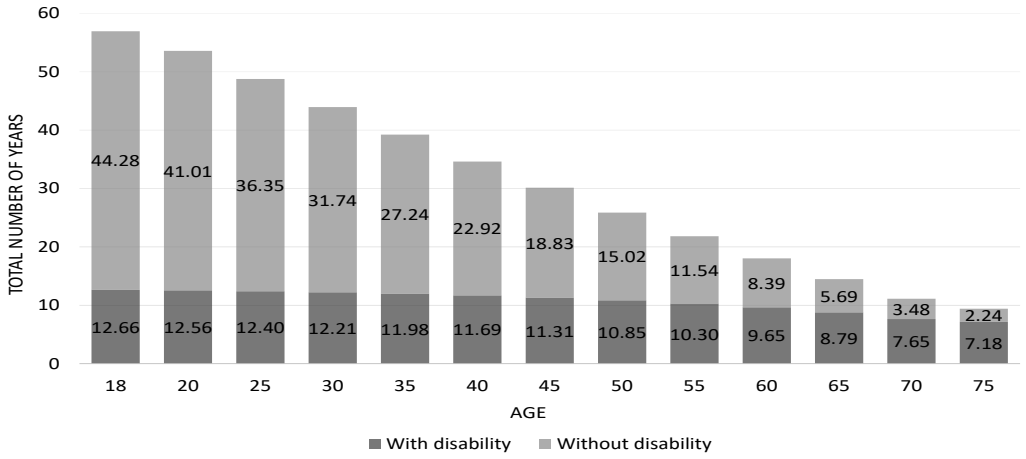
Figure 1. Disability Life Expectancy (DFLE) versus Disability-Free Life Expectancy for 2015 (a) and 2019 (b)

In addition, Figure 1 demonstrates the trends of disability life expectancy (full lines) and disability-free life expectancy (dashed lines) by age in both years. Both lines show a declining trend. It can be seen from Figure 1 that the disability-free life expectancy line is higher than the disability life expectancy for ages 18 to 35, indicating younger population live longer without a disability than with a disability. The trend depicts the same for 2019. However, the expected turning point age population in 2019 to start living with a disability longer than without a disability is delayed by 25 years, i.e., at the age of 60 years old. Compared to a study from Brown (2015), the turning point age for the English and Wales population is expected at 70 years old.

Figure 2 compares the proportion of life spent with and without disability by age groups for 2015 (a) and 2019 (b). The graph shows a declining trend from 18 to 60+ years old in both years, demonstrating that as a person ageing, the proportion of the person's life years spent in a healthy state free of disability is also decreasing. It is due to age-associated physical changes such as reduction in muscle bulk, kidney function and ventilatory capacity (Knott, 2022). According to Hairi et al. (2010), fifty per cent of those aged 75 and above need help with at least one ADL due to physical limitations. The compression of disability is apparent in that the life expectancy with disability (black bar) becomes shorter in 2019 compared to 2015. As an illustration, the life expectancy with a disability for Malaysian older adults aged 60 to 64 decreased from 16.3 years in 2015 to 9.7 years in 2019, demonstrating a 6.6-year delay in the onset of disability. This shows good indications of the population's well-being and health status, of which the proportion of years living without disability has increased tremendously over the four years under the



(a)



(b)

Figure 2. Malaysian total life expectancy by age group segregated by disability and disability-free life expectancies in 2015 (a) and 2019 (b)

study period from year 2015 to 2019.This result is consistent with a study (Fries, 2000) that indicates the postponement of the onset of disability among seniors in the United States is a minimum of 10 years due to improvement in age-specific health status as a result of a reduction in the average cumulative morbidity and disability over the life years. On the contrary, a study in the Philippines showed that an increase in life expectancy comes with a significant increase in the proportion of remaining life in an unhealthy state for all ages and genders, leading to an expansion of morbidity (Cruz et al., 2022). Comparison with these current studies concludes that Malaysia's disability data shows a solid progression in health status, with disability rates decreasing over time in conformity with morbidity compression trends in some developed nations.

In light of the morbidity compression outcomes, the proportion of life spent free from disability improved significantly between years in which the number of years spent without disability in 2019 is substantially higher than in 2015. Subsequently, the proportion of life spent with disability in 2019 is lower than in 2015. As mentioned by the Director-General of WHO "Healthy life expectancy is a key indicator of the nation's health. Increased longevity without quality of life is an empty prize" (Wolf & Laditka,1997). The improvement in disability among Malaysian elderlies is due to government initiatives in establishing national and social strategies focusing on older people. It includes the agenda of raising the standards of living for elderlies (Department of Social Welfare, 2021).

CONCLUSION

Changes in lifestyle and medical technology that hamper the onset of chronic illness and disability has recently become a major topic of discussion among researchers and public health practitioners. The information of disability-free life expectancy has also attracted the attention of insurance firms particularly those who provide medical and health care coverage. This study explores the possibility of estimating the disability prevalence rates by observing the effect of declining trend that could delay the onset of disability at later ages. The comparison of DFLE between the two observation years, showed that as Malaysia's population lived longer with the anticipated number of years without a disability rose remarkably, and the number of years with at least one impairment condition decreased indicating disability compression towards later years. Future research could be carried out by both genders and by the severity levels of disability. Overall, this research can be a good start for future studies on DFLE in Malaysia. In order to understand the significant impact of morbidity compression on the government health care levels of spending, it would be beneficial to the country if future works investigate the relationship between the increase in disability free life expectancy and the costs for medical services.

The comparison of DFLE between the two observation years showed that as Malaysia's population lived longer, the anticipated number of years without a disability rose remarkably, and the number of years with at least one impairment condition decreased. It shows good indications of the population's well-being and health status, of which the proportion of years living without disability has increased tremendously over the four years under study (2015-2019). The results of the DFLE also revealed that almost estimations are linearly declined, demonstrating a decreasing trend across all ages. It indicates an increased risk of physical restrictions as the person ageing.

It is believed that this study would be more comprehensive and meaningful if the calculations of DFLE could be carried out on both genders and by the severity levels of disability. At the same time, initiating and incorporating social, psychological, and biological aspects in the longitudinal study is more appropriate. These additional factors

may help better identify the potential risk factors that could assist in designing and introducing more robust prospective interventions and measures.

Overall, this research can be a good start for future studies on DFLE in Malaysia. Healthy life expectancy is a key indicator of the nation's health. As the Director-General of WHO mentioned in the mid-1990s, "Increased longevity without quality of life is an empty prize" (Wolf & Laditka,1997). In order to understand the significant impact of morbidity compression on the government health care levels of spending, it would be beneficial to the country if future works investigate the relationship between the increase in disability-free life expectancy and the costs for medical services.

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REFERENCES

Ahmad, N. A., Mohamad Kasim, N., Mahmud, N. A., Mohd Yusof, Y., Othman, S., Chan, Y. Y., Abd Razak, M. A., Yusof, M., Omar, M., Abdul Aziz, F. A., Jamaluddin, R., Ibrahim Wong, N., & Aris, T. (2017). Prevalence and determinants of disability among adults in Malaysia: Results from the National Health and Morbidity Survey (NHMS) 2015. *BMC Public Health*, *17*(1), 1-10. https://doi.org/10.1186/s12889-017-4793-7

Brønnum-Hansen, H., Eriksen, M. L., Andersen-Ranberg, K., & Jeune, B. (2017). Persistent social inequality in life expectancy and disability-free life expectancy: Outlook for a differential pension age in Denmark? *Scandinavian Journal of Public Health*, *45*(4), 459-462. https://doi.org/10.1177/1403494816683591

Brown, G. C. (2015). Living too long: Republican time in cooper's leatherstocking novels. *Nineteenth-Century Literature*, *77*(1), 29-55. https://doi.org/10.1525/ncl.2022.77.1.29

Cruz, G. T., Cruz, C. J. P., & Saito, Y. (2022). Is there compression or expansion of morbidity in the Philippines? *Geriatrics & Gerontology International*, *22*(7), 511-515. https://doi.org/10.1111/ggi.14398

Department of Social Welfare. (2021). *Older person*. Department of Social Welfare. https://www.jkm.gov.my/jkm/index.php?r=portal/submenu&id=UkQ5T2ZCTlVkeWFYU2pJZGM5QlE5UT09

Dudel, C., & Myrskylä, M. (2020). Estimating the number and length of episodes in disability using a Markov chain approach. *Population Health Metrics*, *18*(1), 1-9. https://doi.org/10.1186/s12963-020-00217-0

Fries, J. F. (2000). Compression of morbidity in the elderly. *Vaccine*, *18*(16), 1584–1589. https://doi.org/10.1016/S0264-410X(99)00490-9

Fries, J. F., Bruce, B., & Chakravarty, E. (2011). Compression of morbidity 1980-2011: A focused review of paradigms and progress. *Journal of Aging Research*, *2011*, Article 261702. https://doi.org/10.4061/2011/261702

Hairi, N. N., Bulgiba, A., Cumming, R. G., Naganathan, V., & Mudla, I. (2010). Prevalence and correlates of physical disability and functional limitation among community dwelling older people in rural Malaysia, a middle income country. *BMC Public Health*, *10,* 1-13. https://doi.org/10.1186/1471-2458-10-492

Ibrahim, N. S. M., Shair, S. N., & Yusof, A. Y. (2020). Mortality rates and life expectancy improvements among Malaysian elderlies. *Indonesian Journal of Electrical Engineering and Computer Science*, *19*(1), 134-139. https://doi.org/10.11591/ijeecs.v19.i1.pp134-139

Imai, K., & Soneji, S. (2012). On the estimation of disability-free life expectancy: Sullivan's method and its extension. *Journal of the American Statistical Association*, *102*(480), 1199-1211. https://doi.org/10.1198/016214507000000040

Jagger, C., Oyen, H. Van, & Robine, J. M. (2014). Health expectancy calculation by the sullivan method: A practical guide. *Newcastle University Isntitute of Ageing*. http://www.eurohex.eu/pdf/Sullivan_guide_pre final_oct 2014.pdf

Jagger, C., Robine, J. M., Van Oye, V. O., Cox, B., Cambois, E., Romieu, I., Clavel, A., & Le Roy, S. L. (2007). *Health Expectancy Calculation by the Sullivan Method: A Practical Guide* [EHEMU Technical report 2006_3]. https://webgate.ec.europa.eu/chafea_pdb/assets/files/pdb/2006109/2006109_d5sullivan_guide_final_jun2007.pdf

Knott, L. (2022). *Disability in older people (Causes and treatment)*. Patient. https://patient.info/doctor/disability-in-older-people

Macrotrends.net. (2023). Malaysia Life Expectancy 1950-2023. https://www.macrotrends.net/countries/MYS/malaysia/life-expectancy

Ministry of Economy (2021). *Abridged life table, Malaysia 2019-2021*. Department of Statistics Malaysia. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.dosm.gov.my/site/downloadrelease?id=abridged-life-tables-malaysia-2019-2021&lang=English

Mathers, C. D. M., Sadana, R., Salomon, J. A., Murray, C. J., & Lopez, A. D. (2000). *Estimates of DALE for 191 countries: Methods and results* (Working Paper No. 16). World Health Oreganization. https://www.who.int/healthinfo/paper16.pdf%0Ahttp://www.who.int/entity/healthinfo/paper16.pdf

Minagawa, Y., & Saito, Y. (2018). An analysis of factors related to disability-free life expectancy at 65 years of age across Japanese prefectures in 2010. *European Journal of Ageing*, *15*(1), 15-22. https://doi.org/10.1007/s10433-017-0433-4

Moreno, X., Albala, C., Lera, L., Leyton, B., Angel, B., & Sánchez, H. (2018). Gender, nutritional status and disability-free life expectancy among older people in Santiago, Chile. *PLoS ONE*, *13*(3), 1-10. https://doi.org/10.1371/journal.pone.0194074

Moreno, X., Lera, L., & Albala, C. (2020). Disability-free life expectancy and life expectancy in good self-rated health in Chile: Gender differences and compression of morbidity between 2009 and 2016. *PLoS ONE*, *15*(4), 1-12. https://doi.org/10.1371/journal.pone.0232445

National Institute of Health (2019). *NCDs - Non-communicable diseases: Risk Factors and other health problems* (Technical Report Vol. 1). National Institutes of Health. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://iku.gov.my/images/IKU/Document/REPORT/NHMS2019/Report_NHMS2019-NCD_v2.pdf

Omar, M. H., Asmuni, N. H., & Shima, S. N. (2019). Healthy life expectancy vs health expenditure by sullivan method in Malaysia. *Indonesian Journal of Electrical Engineering and Computer Science*, *14*(1), 402-406. https://doi.org/10.11591/ijeecs.v14.i1.pp402-406

Prina, A. M., Wu, Y. T., Kralj, C., Acosta, D., Acosta, I., Guerra, M., Huang, Y., Jotheeswaran, A. T., Jimenez-Velazquez, I. Z., Liu, Z., Llibre Rodriguez, J. J., Salas, A., Sosa, A. L., & Prince, M. (2020). Dependence-and disability-free life expectancy across eight low- and middle-income countries: A 10/66 study. *Journal of Aging and Health*, *32*(5-6), 401-409. https://doi.org/10.1177/0898264319825767

Romero, D. E., Leite, I. da C., & Szwarcwald, C. L. (2005). Healthy life expectancy in Brazil: applying the Sullivan method. *Cadernos de Saúde Pública / Ministério Da Saúde, Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública*, *21*(suppl 1), S7-S18. https://doi.org/10.1590/s0102-311x2005000700002

Stiefel, M. C., Perla, R. J., & Zell, B. L. (2010). A healthy bottom line: Healthy life expectancy as an outcome measure for health improvement efforts. *The Milbank Quarterly*, *88*(1), 30-53. https://doi.org/10.1111/j.1468-0009.2010.00588.x

United Nations. (2019). *World population ageing 2019*. United Nations. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Highlights.pdf

Wolf, D. A., & Laditka, S. B. (1997). *Stochastic modeling of active life and its expectancy* [Working Paper]. Center for Policy Research. https://surface.syr.edu/cpr/419/

Yong, V., & Saito, Y. (2009). Trends in healthy life expectancy in Japan: 1986-2004. *Demographic Research*, *20*, 467-494. https://doi.org/10.4054/DemRes.2009.20.19