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ORIGINAL RESEARCH ARTICLE

# Mapping of the World Health Organization Quality of Life Brief (WHOQOL-BREF) to the EQ-5D-5L in the General Thai Population

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## Abstract

**Purpose** This study aimed at mapping the World Health Organization Quality of Life Brief (WHOQOL-BREF) and the EQ-5D-5L in the general Thai population and to determine the impact on the incremental cost-utility ratio (ICUR) through five hypothetical scenarios.

**Methods** A total of 1,200 Thai participants were randomly allocated into the 'estimation' and 'validation' groups. A curve estimation with nine regression models was performed to identify the best-fit regression model of significant WHOQOL-BREF dimension scores for the EQ-5D-5L index score predictions in the estimation group. The identified model was then used for the calculation of the predicted EQ-5D-5L index scores in the validation group. The percentage change from the hypothetical base-case scenario with predefined parameters was used to determine the impact on the ICUR.

**Results** An inverse model was the best-fit regression model to predict the EQ-5D-5L index scores. The absolute difference between the predicted and observed index scores was 0.064, and the percentage of the sample that was mispredicted by ≥ 0.05 and ≥ 0.1 was 43.8% and 16.8%, respectively. Moreover, the percentage change in ICUR ranged between 0.13 and 1.84% from the hypothetical base-case scenario.

**Conclusions** An inverse relationship between the studied scores was identified. The minimal impact on the ICUR suggests that the Health Utility Index of the mapped equation can be applied to economic analyses.


## 1 Introduction

Health-related quality of life (HRQoL), a multidimensional construct, enables us to determine the specific effects of health, illness, and treatment on an individual's quality of life [1]. Moreover, it is considered a main type of patient-reported outcome that can be used to assess the impact of disease and health intervention on overall health, from the individual's perspective, in various areas, including health research, clinical practice, and health policy [2–4]. A multiple-attribute instrument is increasingly used for the assessment and measurement of HRQoL levels in healthy individuals and those with various levels of impaired health conditions, thereby enabling level comparisons across a wide range of populations [5–9].

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Generic instruments are commonly used to measure HRQoL levels. In fact, they are designed for the assessment of HRQoL levels in a wide range of populations so that they can enable comparisons between condition-specific and general populations; nevertheless, their responsiveness to health changes and their relevance to some groups are limited [6].

Within the generic instrument, profile scores are reported for each health dimension or in the form of a single index score, known as a 'health utility score' [6]. The health utility score generally reflects the relative societal desirability of a particular health state, which is anchored by '0' (the worst possible health state or dead) and '1' (an optimal level of health state or full health) [10–12]. It can also generate quality-adjusted life-years (QALYs) [13]—a health outcome that combines survival time with the health utility score and that is also considered as a main outcome for cost-utility analyses (CUAs) [14, 15]. The health utility score is often estimated using an indirect method in which participants are required to complete a preference-based instrument. Subsequently, a country-specific value set of the used preference-based instrument is employed to transform the participant's health state into a health utility score

**Key Points for Decision Makers**

No previous studies have been conducted regarding the relationship between the EQ-5D-5L and the World Health Organization Quality of Life Brief (WHOQOL-BREF) in the general Thai population.

The WHOQOL-BREF physical domain was associated with the EQ-5D-5L index score using the Thai value set.

An inverse relationship is the best-fit regression model to predict the EQ-5D-5L index score. However, the mapping equation should be further investigated with larger numbers of the Thai population.

[16]. Several preference-based measures are currently used, including the EQ-5D, the Health Utility Index (HUI), and the Short Form-6 Dimension (SF-6D) [6, 17–19].

Although the preference-based instrument is essential for undertaking economic analyses, the health profile instrument is often used in clinical trials and clinical studies because it can provide more comprehensive information along with a profile score for each health dimension and may be more sensitive to clinical changes. Some profile-based instruments are the Sickness Impact Profile, Nottingham Health Profile, and WHOQOL–BREF [6, 20]. In an attempt to retain the benefit of using profile-based instruments in clinical studies and providing a health utility score for economic analyses, great interest has been expressed in combining preference- and profile-based instruments by mapping or through the linking approach [21–23].

The World Health Organization Quality of Life-100 (WHOQOL-100) is a profile-based instrument originally developed by the WHO in collaboration with 15 international centres (including Thailand) for cross-cultural use in HRQoL assessment [20]; however, the WHOQOL-100 contains a total of 100 questions, making it lengthy for use in a large population survey [20]. Therefore, the 26-item WHO Quality of Life Brief (WHOQOL-BREF) was developed as an abridged WHOQOL-100 version. It is more practical and has now been widely used across the globe. A Thai-language version of the WHOQOL-BREF is also available [24]. Previous evidence has revealed that the WHOQOL-BREF is a valid, reliable, and practical instrument for the undertaking of a HRQoL assessment in the general Thai population [25], in elderly Thai individuals [26], and in those patients with medical conditions such as cancer [27] or human immunodeficiency virus/acquired immunodeficiency syndrome [28].

Given its simplicity and self-completion with low-cost burden, the EQ-5D is the most commonly used health preference-based questionnaire. It was developed by the EuroQoL group in the 1980s [29]. The EQ-5D is widely used for the calculation of QALYs for CUA and is recommended by many health technology assessment (HTA) guidelines, including those from Thailand [10, 30–33]. The first version of the EQ-5D is the EQ-5D-3L, with three response options for the measurement of the current participant's health status. However, its high ceiling effect and low discriminant activity are the two main psychometric problems encountered with its use. To eliminate these problems, a newer version of the EQ-5D, the EQ-5D-5L (with five response options), was developed, and several studies have certified its lower ceiling effect and higher discriminant activity in the general population and in several therapeutic areas [34–37]. Thai evidence has also suggested that the EQ-5D-5L is a valid, reliable, and practical instrument for the assessment of HRQoL and that it is characterized by a lower ceiling effect and an enhanced discriminative power than the EQ-5D-3L in the general Thai population and in patient groups [38, 39]. Therefore, the EQ-5D-5L has become the HRQoL instrument that is widely used to elicit the health utility score for economic analyses in Thailand and is highly recommended by the Thai HTA guideline [40].

To date, only two studies have attempted to map the WHOQOL-BREF to the EQ-5D-5L in Singaporean people [41] and Thai patients with chronic diseases [42]. However, the Singaporean study employed the Japanese value set (that was provided from the EuroQoL group's crosswalk project) when estimating the health utility score of the EQ-5D-5L from the EQ-5D-3L, given the fact that a Singaporean value set was not available [41, 43]. Conversely, the Thai study mapped the WHOQOL-BREF to the EQ-5D-5L using the Thai value set in patients with chronic diseases, and revealed a non-linear relationship between the WHOQOL-BREF physical health dimension score and the EQ-5D-5L utility index score. However, no evidence of mapping the WHOQOL-BREF and the EQ-5D-5L using the Thai value set in the general Thai population has yet been provided. Therefore, this study aimed at (1) mapping the WHOQOL-BREF and the EQ-5D-5L in the general Thai population using the Thai value set; and (2) determining the economic impact on the incremental cost-utility ratio (ICUR) using the differences between the observed and predicted EQ-5D-5L index scores.

## 2 Methods

### 2.1 Study Samples and Settings

This study was part of the project titled 'Psychometric properties comparison between EQ-5D-5L and EQ-5D-3L in the general Thai population' [38]. Convenience sampling was performed to recruit 1,200 general Thai participants residing in five provinces of Thailand: Nakhon Sri Thammarat, Khon-Kaen, Chonburi, Chiang-Mai, and Bangkok (the capital city). The inclusion criteria were age 20–70 years and the ability to understand Thai and complete the interview process. Participants with an acute or life-threatening illness, cognitive impairment or disability were excluded. A four-stage, stratified, random-sampling method was employed to select the provinces, districts, subdistricts, and villages. The five provinces were randomly selected to represent a province from each region of Thailand, whereas districts, subdistricts, and villages were randomly selected within each province. Each available participant who met the eligibility criteria was selected by the local village leader of each village in proportions of age and sex that represented the general Thai population.

### 2.2 Data Collection

Face-to-face interviews were conducted at the participant's residences between July and September 2019, and written informed consent was obtained from all participants. A cash allowance of US dollars (US$) 3.3 (1 US$ = 33 Thai Baht [THB]) was given to each participant for their time compensation. Ethical approval for the undertaking of this study was obtained from the Burapha University Institutional Review Board (BUU-IRB; 108/2562).

### 2.3 Instruments

#### 2.3.1 EQ-5D-5L

The official Thai version of the EQ-5D-5L was developed by the EuroQoL group. The EQ-5D-5L has five dimensions: mobility (MO), self-care (SC), usual activities (UA), pain/discomfort (PD) and anxiety/depression (AD). Each of these dimensions has five response options: no problem, slight problem, moderate problem, severe problem, and extreme problems/unable to perform. Participants were required to indicate their health status for the day that interviews were performed by selecting one response option per dimension, resulting in a 5-digit health descriptive system for the health utility score calculation. Health utility score was computed using the Thai value set of the EQ-5D-5L, with a possible range of – 0.4212 to 1 [44], where a negative value indicates a health state worse than dead, while '0' and '1' represent dead and the full health state, respectively.

#### 2.3.2 WHOQOL-BREF

Permission to use the WHOQOL-BREF was granted by the Director of the Suan Prung Psychiatric Hospital, Thailand [25]. Participants were asked to rate their health status during the past 2 weeks. The WHOQOL-BREF contains 24 items categorized into four dimensions: physical health (seven items), psychological health (six items), social relationships (three items), and environment (eight items). Furthermore, two additional items for general health and overall quality of life were added to the list, thereby giving a total of 26 items. Response options were on a 5-point Likert-scale: 1, not at all; 2, not much; 3, moderately; 4, a great deal; and 5, completely. Three negatively worded items (numbers 2, 9 and 11) were reverse scored. Here, the raw scores were derived from the summation of the item scores within each dimension, and the mean of the non-missing item scores was used to replace the missing item scores in the same dimension [41].

### 2.4 Data Analysis

All data analyses were performed in the same way as in the study by Sakthong [42], which compared the results between two groups of the Thai population; however, this study also employed a secondary data analysis.

A total of 1,200 participants with non-missing values in four WHOQOL-BREF domains were randomly allocated into two groups with equal numbers of participants: (1) the 'estimation' group ($n = 600$) and (2) the 'validation' group ($n = 600$). To report the participant characteristics for each group, descriptive statistics were employed in which the frequency and percentage were used for categorical variables (such as sex, education level, and marital status), while the mean and standard deviation (SD) were computed for continuous variables (such as age, income and number of diseases). Independent *t* test and Chi-square tests were used where appropriate to examine whether the participant characteristics were different between the two groups.

In the estimation group, the relationship between the WHOQOL-BREF dimension scores and the EQ-5D-5L index scores was investigated using multiple linear regression. A curve estimation approach was employed to find the most appropriate regression model between the significant WHOQOL–BREF dimension scores and the EQ-5D-5L index score predictions. To find the best-fit regression model from the curve estimation approach, nine different regression models covering both linear and non-linear regressions, including logarithmic, inverse, quadratic, cubic, power, s, growth, and exponential, were used to predict the values of dependent variables from one independent variable. It is considered an appropriate approach when the relationship between the dependent and independent variables is not necessarily linear [45]. In this study, the nine different regression models were employed to investigate the best-fit regression model to predict the EQ-5D-5L index scores as dependent variables from the significant dimension of WHOQOL–BREF scores as respective independent variables.

Three goodness-of-fit indexes—adjusted R-square, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC)—were used for the determination of the most appropriate regression model. The regression model contributing to the lowest AIC and BIC values and highest adjusted R-square was regarded as the best-fit regression model to predict the EQ-5D-5L index scores.

In the validation group, the best-fit regression model from the estimation group was used to compute the predicted EQ-5D-5L index scores. Agreement between the predicted and observed EQ-5D-5L index scores was determined using intraclass correlation coefficients (ICCs), ranging from 0.00 to 1.00. The ICCs were computed by a two-way mixed effects model, absolute agreement, and average measures. Rosner's guideline was employed to determine the agreement level as follows: poor agreement (ICCs < 0.40), good agreement (0.40 ≤ ICCs < 0.75), and excellent agreement (ICCs ≥ 0.75) [46]. A Bland–Altman plot was also employed for determination of the agreement between the observed and predicted EQ-5D-5L index scores by plotting the differences between the two scores (y-axis) and the mean of these two scores (x-axis) [47]. The mean difference (d) and the 95% limits of differences were indicated with dotted lines. The 95% limits of agreement were calculated using the following formula (Eq. 1) [47]:

$$d \pm 1.96 \times \text{SD of } d. \qquad (1)$$

A difference between the observed and predicted EQ-5D-5L index scores falling within the 95% limits of agreement indicates good agreement between the two scores. Furthermore, the mean absolute error (MAE) and mean squared error (MSE) were calculated to measure the errors between the predicted and observed EQ-5D-5L index scores. MAE and MSE were calculated using the following formulas (Eqs. 2 and 3) [48, 49]:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|y_i - x_i\right| \qquad (2)$$

$$\text{MSE} = \frac{\sum_{i=1}^{n}\left(y_i - x_i\right)^2}{n}, \qquad (3)$$

where $n$ is the sample size, $y_i$ is the observed EQ-5D-5L index score for the $i$th observation, and $x_i$ is the predicted EQ-5D-5L index score for the $i$th observation.

All statistic analyses were conducted using IBM SPSS version 23 (IBM Corporation, Armonk, NY, USA), except the AIC and BIC values, which were computed using STATA 17 (StataCorp LLC, College Station, TX, USA), with a $p$-value < 0.05 being considered as statistically significant.

*Impact on the Incremental Cost-Utility Ratio* A hypothethical situtation of a new drug (drug A) that is compared with an existing drug (drug B) was created to examine the impact of the differences between the observed and predicted EQ-5D-5L index scores on the ICUR, using five hypothetical decision trees. Table 1 displays the parameters considered for economic analyses of this hypothetical base-case scenario. Scenario 1 represents the hypothetical base-case scenario (decision tree 1). Decision trees 2 and 4 were overestimated and underestimated by a mean difference, while descision trees 3 and 5 were overestimated and underestimated by a median difference. The ICUR between the incremental cost (cost of drug A minus the cost of drug B) divided by the incremental QALY (QALY of drug A minus the QALY of drug B) was calculated. The impact of the ICUR was computed and reported as a percentage change of scenarios 2–5 (decision trees 2–5) from the hypothetical base-case scenario (decision tree 1).

## 3 Results

As shown in supplementary Table 1, the participant characteristics of the estimation ($n$ = 600) and validation groups ($n$ = 600) were not significantly different. No missing values were reported for any of the collected parameters. As a result, the data analyses were performed with a total of 1,200 participants.

**Table 1** Hypothetical base-case scenario for economic analyses

| Parameters | A (new treatment) | | B (conventional treatment) | |
|---|---|---|---|---|
| | Success | Failure | Success | Failure |
| Probability of treatment results | 0.8 | 0.2 | 0.7 | 0.3 |
| Survival (years) | 6 | 4 | 5 | 3 |
| Utility index scores | 0.9 | 0.6 | 0.8 | 0.5 |
| Cost (Baht) | 50,000 | 45,000 | 40,000 | 39,500 |

In the estimation group, the observed scores for the WHOQOL-BREF dimension and the EQ-5D-5L index covered a broad range: WHOQOL-BREF physical health (range 16–35), WHOQOL-BREF psychological health (range 8–30), WHOQOL-BREF social relationships (range 4–15), WHOQOL-BREF environment (range 13–40) and EQ-5D-5L (range 0.23–1.00). Nevertheless, the lowest possible EQ-5D-5L index and WHOQOL-BREF domain scores were not observed.

Table 2 presents the relationship between the WHOQOL-BREF dimension scores and the EQ-5D-5L index scores. The multiple linear regression suggested that only the WHOQOL-BREF physical health domain was associated with the EQ-5D-5L index scores ($p < 0.01$).

As shown in Table 3, when the EQ-5D-5L index scores were mapped onto the WHOQOL-BREF physical health domain, the estimation curve indicated that the inverse model was the best-fit regression model for prediction of the EQ-5D-5L index scores, as it yielded the lowest AIC (− 1232.45) and BIC (− 1223.66) and highest adjusted R-square (0.223) among the nine regression models assessed. The inverse model mapping equation was as shown in Eq. 4:

$$\text{EQ-5D-5L index scores} = 1.252 - 8.446 / \text{WHOQOL-BREF physical health domain scores.} \quad (4)$$

According to the inverse model mapping equation, it should be noted that when the WHOQOL-BREF physical health domain reached its maximum score of 35, the mapped utility scores exceeded the full health of the EQ-5D-5L index scores of 1.00. In this case, it was limited to a maximum value of 1.00 to produce the full health representation of the EQ-5D-5L index scores.

**Table 3** Goodness-of-fit index of nine different regression models for the Thai EQ-5D-5L

| Models | Thai EQ-5D-5L | | |
|---|---|---|---|
| | AIC | BIC | Adjusted R-square |
| Linear | − 1221.80 | − 1213.01 | 0.209 |
| Logarithmic | − 1228.58 | − 1219.78 | 0.218 |
| Inverse | − 1232.45[a] | − 1223.66[a] | 0.223[a] |
| Quadratic | − 1191.58 | − 1178.39 | 0.208 |
| Cubic | − 1230.65 | − 1213.06 | 0.223[a] |
| Power | − 1226.41 | − 1217.61 | 0.189 |
| S | − 1231.46 | − 1222.66 | 0.196 |
| Growth | − 1218.84 | − 1210.05 | 0.179 |
| Exponential | − 1218.84 | − 1210.05 | 0.179 |

*AIC* Akaike Information Criterion, *BIC* Bayesian Information Criterion

[a]Lowest AIC and BIC values and highest adjusted R-square

Table 4 summarizes the descriptive statistics of the observed and predicted EQ-5D-5L index scores, as well as their differences in the validation group. It was revealed that the average of the predicted score (0.930) was slightly lower than that of the observed score (0.931), resulting in an absolute difference score between the observed and predicted scores of 0.064. Moreover, the MAE and MSE were found to be 0.065 and 0.008, respectively. It should be noted that the percentage of samples that were mispredicted by ≥ 0.05 and ≥ 0.1 of the absolute difference of utility scores was 43.8% and 16.8%, respectively.

The agreement level of the observed and predicted EQ-5D-5L index scores in the validation group was good, with an ICC of 0.543 (95% confidence interval [CI] 0.464–0.611). The Bland–Altman plot of the difference between the observed and predicted EQ-5D-5L is shown in Fig. 1. It was found that the mean difference was 0.001, with 95.3% falling within the 95% limit of the mean difference of − 0.1754 and 0.1774, while 4.5% and 0.2% were below and over the 95% limits of the differences, respectively. In comparison with the predicted EQ-5D-5L index scores, it was also revealed that 36.7% of the observed scores were lower (< 0), 4.8% were equal, and 58.5% were higher (> 0).

Table 5 displays the impact of the mean and median differences between the observed and predicted EQ-5D-5L

**Table 2** Impact of the WHOQOL-BREF dimensions on the utility index scores of the Thai EQ-5D-5L for the estimation group (results were obtained by using a multiple regression analysis)

| WHOQOL-BREF domains (predictors) | Thai EQ-5D-5L | | |
|---|---|---|---|
| | Regression coefficients | 95% CI | *p*-value |
| Constant | 0.569 | 0.511 to 0.628 | < 0.001 |
| Physical | 0.011 | 0.007 to 0.014 | < 0.001 |
| Psychological | 0.002 | − 0.001 to 0.006 | 0.192 |
| Social | 0.003 | − 0.003 to 0.008 | 0.345 |
| Environment | $-7.868\times10^{-5}$ | −0 .003 to 0.003 | 0.954 |

*WHOQOL-BREF* World Health Organization Quality of Life Brief, *CI* confidence interval

**Table 4** Descriptive statistics of the observed and predicted Thai EQ-5D-5L index scores, and the difference score of the validation sample

| Score | Mean | SD | Median | Interquartile | Range |
|---|---|---|---|---|---|
| Thai EQ-5D-5L | | | | | |
| Observed score | 0.931 | 0.104 | 1.000 | 0.885–1.000 | 0.233–1.000 |
| Predicted score | 0.930 | 0.046 | 0.939 | 0.904–0.961 | 0.650–1.001 |
| Absolute difference (observed–predicted scores) | 0.064 | 0.062 | 0.050 | 0.029–0.086 | 0.001–0.550 |

*SD* standard deviation

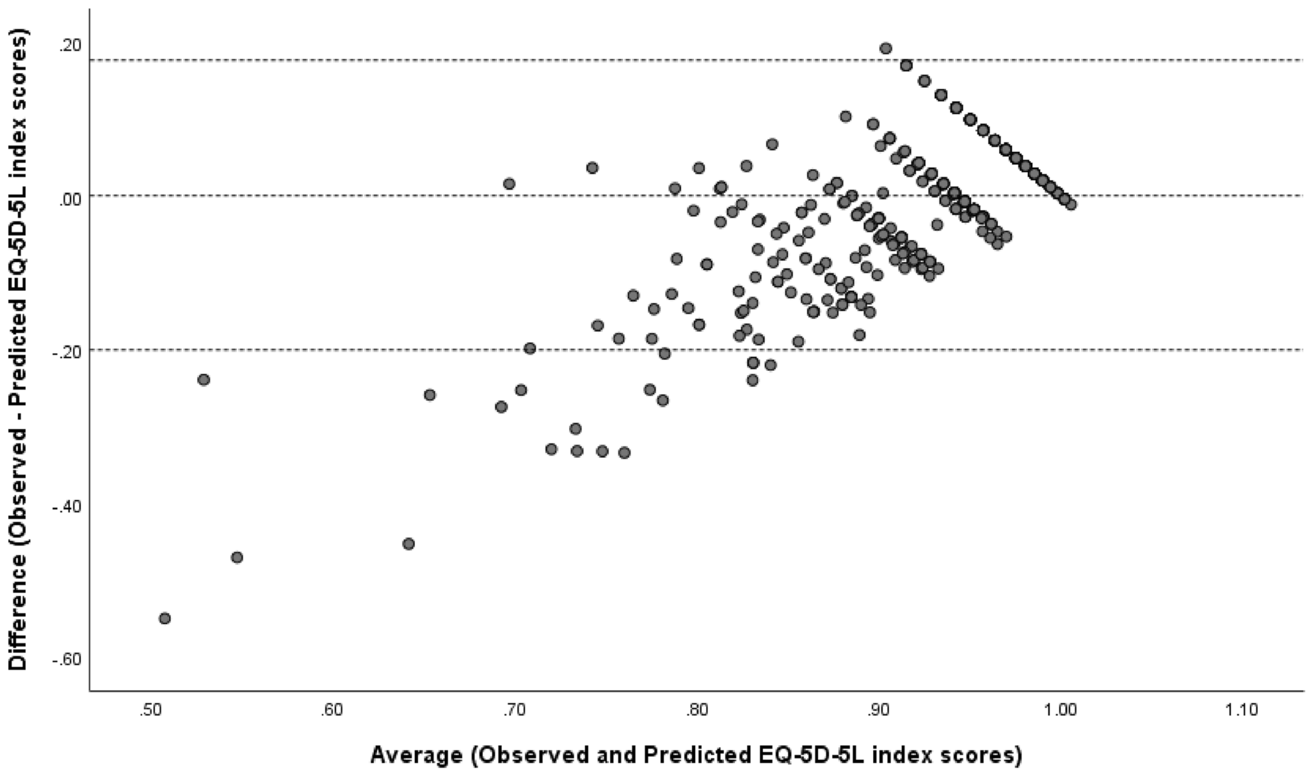


**Fig. 1** Bland–Altman plot between the difference and average of observed and predicted EQ-5D-5L index scores

index scores based on the five hypothetical scenarios that were assessed. In this analysis, an incremental cost was fixed at THB 15,500 for five hypothetical scenarios (including the base-case scenario), while the incremental QALY varied depending on the scenario. It was found that an incremental QALY value of 1.55 yielded an ICUR of 10,000 (15,500/1.55) Baht/QALY gain in the hypothetical base-case scenario. In the other four hypothetical scenarios, the utility index scores were overestimated and underestimated by a mean of 0.001 (scenarios 2 and 4) and a median of 0.024 (scenarios 3 and 5) differences from the hypothetical base-case scenario, yielding incremental QALYs of between 1.522 and 1.576, and resulting in an ICUR ranging from a 9,835 to 10,184 Baht/QALY gain. Therefore, the percentage change in the ICUR was between 0.13 and 1.84% from the base-case scenario.

## 4 Discussion

This was the first study attempting to map two widely used generic instruments for the assessment of HRQoL—the WHOQOL-BREF and the Thai EQ-5D-5L—using a Thai value set derived from the general Thai population. A curve estimation containing nine regression models was employed to identify the best-fit regression model for prediction of the EQ-5D-5L index scores based on the WHOQOL-BREF.

**Table 5** Results of the incremental cost-utility ratios obtained from the mean and median differences between the observed and predicted EQ-5D-5L index scores, for five hypothetical scenarios

| Variables | Hypothetical base-case scenario | Hypothetical scenarios | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| EQ-5D-5L utility index scores if the treatment was successful | | | | | |
| Treatment A | 0.9 | 0.901 | 0.924 | 0.899 | 0.876 |
| Treatment B | 0.8 | 0.801 | 0.824 | 0.799 | 0.776 |
| EQ-5D-5L utility index scores if the treatment was unsuccessful | | | | | |
| Treatment A | 0.6 | 0.601 | 0.624 | 0.599 | 0.576 |
| Treatment B | 0.5 | 0.501 | 0.524 | 0.499 | 0.476 |
| QALY values | | | | | |
| Treatment A | 4.8 | 4.806 | 4.934 | 4.794 | 4.666 |
| Treatment B | 3.25 | 3.254 | 3.356 | 3.246 | 3.144 |
| Incremental QALY | 1.55 | 1.552 | 1.576 | 1.548 | 1.522 |
| Incremental cost (Baht) | 15,500 | 15,500 | 15,500 | 15,500 | 15,500 |
| Incremental cost-utility ratios | 10,000 | 9,987 | 9,835 | 10,013 | 10,184 |
| Percentage differences of incremental cost-utility ratios from the hypothetical base-case scenario | NA | 0.13 | 1.65 | 0.13 | 1.84 |

*NA* not assessed, *QALY* quality-adjusted life-years

Similar to previous studies undertaken on Singaporean [41] and Thai patients with chronic diseases [42], a multiple linear regression suggested that the WHOQOL-BREF physical dimension was only associated with the EQ-5D-5L index score. A possible explanation for this is that four (MO, SC, UA and PD) out of five dimensions of the EQ-5D-5L are designed to measure the participant's current health status in relation to physical health, thereby resulting in a statistically significant relationship between the WHOQOL-BREF physical health dimension and the EQ-5D-5L index score. Consistent with a previous study [50], the EQ-5D-5L was more sensitive to the physical health dimension than to the psychosocial dimension, as compared with other generic HRQoL instruments (including the SF-6D, HUI 3, 15-dimensional [15D], and Assessment of Quality of Life-8 Dimension [AQoL-8D]). Additionally, the sample characteristics might account for this phenomenon because the sample of recruited patients reported themselves as having chronic diseases mainly related to physical illness; therefore, the regression results showed significant associations between the EQ-5D-5L index scores and WHOQOL–BREF physical health dimension. Similarly, the study by Sakthong [42] also found an association between the EQ-5D-5L index scores and physical WHOQOL–BREF, although that study was conducted with Thai chronic patients and mainly related to physical illnesses. Consequently, a future study should develop a mapping equation between the EQ-5D-5L index scores and WHOQOL–BREF among a sample of patients with more varied health conditions covering both physical- and psychological-related illnesses.

An inverse relationship between the WHOQOL-BREF physical health dimension score and the EQ-5D-5L index score was identified because it yielded the lowest AIC and BIC and highest adjusted R-square among the regression models. In line with the study by Sakthong [42], this also showed an inverse relationship between the WHOQOL-BREF physical health dimension score and the EQ-5D-5L index score.

According to the inverse relationship, it was characterized by a constant term of 1.252 and an inverse term of − 8.446/WHOQOL-BREF physical health dimension score. This finding is similar to those of the studies by Wee et al. [41] and Sakthong [42]; in fact, the study by Wee et al. [41] identified a two-degree fractional polynomial with power terms of − 2 and 0.5, while the study by Sakthong [42] showed that an inverse relationship was the best-fit regression model for prediction of the EQ-5D-5L index scores, with a constant term of 1.385 and an inverse term of − 7.572/WHOQOL-BREF physical health dimension score. Furthermore, the MAE of this study was 0.065, which is higher than that reported by Sakthong [42] (0.004) and lower than that reported by Wee et al. [41] (0.091), while the MSE of this study was 0.008, which is lower than that reported by Sakthong [42] and Wee et al. [41] (0.013 and 0.0126, respectively).

As far as the agreement between the observed and predicted EQ-5D-5L index scores is concerned, this study identified an ICC of 0.54, which is lower than that reported by Wee et al. [41] (0.58). However, Rosner's guideline suggests that the ICC values of both studies indicate good agreement between the observed and predicted EQ-5D-5L index scores [46]. The different participant characteristics and value sets employed to elicit the EQ-5D-5L index scores may account for this discrepancy, as the study of Wee et al. [41] employed the Japanese value set obtained from the EuroQoL group's crosswalk project that aimed at estimating the health utility score of the EQ-5D-5L from the EQ-5D-3L of the Singaporean population. Conversely, this study used the Thai value set. The ICC of this study was similar to that reported in the study by Sakthong [42] (0.56), as both studies share some similar characteristics. For example, the study by Sakthong [42] employed the Thai value set to elicit the EQ-5D-5L index scores, although Sakthong focused on Thai patients with chronic diseases. Additionally, the Bland–Alman plot of the observed and predicted EQ-5D-5L index scores demonstrated similar results, as both this study and that of Sakthong [42] identified a similar percentage of differences between the observed and predicted EQ-5D-5L index scores, falling within the limits of agreement (95.3% and 95%, respectively). As a result, these findings suggest that applying one's own value set is better than employing another nation's value set, given the fact that different populations embrace different values and cultures, thereby shaping different standards with regard to HRQoL [20, 51].

In a similar manner to the study by Sakthong [42], approximately 58.5% of the observed EQ-5D-5L index scores were found to be higher than the predicted scores after using the mapped equation. A possible explanation for this is that both studies identified the inverse relationship as the best-fit regression model to predict the EQ-5D-5L index scores. Moreover, the different recalling periods between the two instruments was due to the fact that the WHOQOL-BREF used 'the past 2 weeks' while the EQ-5D-5L used 'today' as the recalling period. Nevertheless, Sakthong [42] has reported that the maximum value of the predicted scores was 0.98, while this study showed that the predicted score was at its maximum score of 1.01, which is similar to that reported by Wee et al. [41]. In the latter, its value was constrained to a maximum value of 1.00, thereby representing the full health utility. This contradiction might be due to different population characteristics. The study by Sakthong [42] was conducted on Thai patients with chronic diseases having various levels of health impairments, and the study participants would have likely reported an impaired level of the WHOQOL-BREF physical health dimension, thereby resulting in a maximum predicted score of 0.98. Conversely, this current study and that of Wee et al. [41] focused on the general Thai and Singaporean populations. In these populations, stable health conditions were observed in higher numbers and allowed for the maximum score of the WHOQOL-BREF physical health dimension to be reached and to yield the exceeded maximum EQ-5D-5L index score. However, it should be noted that the mapped equation in the study by Sakthong [42] can contribute to an exceeded maximum EQ-5D-5L index score of 1.00 when the WHOQOL-BREF physical health dimension score reaches its maximum value. Therefore, future studies should investigate the differences between the predicted EQ-5D-5L index scores obtained using a mapping equation from this study and those reported by Sakthong [42]. Furthermore, these studies should focus on the general Thai population, especially for patients who reported that they had certain chronic diseases, along with the effect on economic analyses of the EQ-5D-5L index scores derived from the two mapped equations.

The percentage change in the ICUR of the differences between the observed and predicted EQ-5D-5L index scores was found to be between 0.13 and 1.84 from the hypothetical base-case scenario. This finding was consistent with that reported by Sakthong [42]; the latter found that the percentage change was only 0.4–1.8% from the base-case scenario. A possible reason for these findings is that both studies identified that an inverse relationship is the best-fit regression model for the prediction of the EQ-5D-5L index score, and they applied the same approach to investigate the impact of differences between the observed and predicted EQ-5D-5L index scores on the ICUR. To confirm this finding, further studies that focus on the effect of differences between the observed and predicted EQ-5D-5L indexes on the ICUR with the real CUA should certainly be conducted. However, the aforementioned finding implies that the WHOQOL-BREF, which is a widely used health profile-based instrument, can provide the Health Utility Index score needed for economic analyses.

Some limitations should be addressed. First, this study found that the range of the raw score for the WHOQOL-BREF physical health dimension was between 16 and 35, while those of a theoretical raw score range between 7 and 35, thereby indicating that the theoretical raw score of the WHOQOL-BREF physical health dimension was not covered by this study. Therefore, the mapped equation should be used with caution in participants with poor WHOQOL-BREF physical health dimension scores. In fact, studies with participants having impaired physical health might need to be re-investigated. Second, the identified mapped equation is only associated with the WHOQOL-BREF physical health dimension, therefore it ought to be used with some limitations on participants with other health conditions (including mental illness). Third, this study examined the mapped equation with a validation sample of 600 participants who were characterized by a limited range of health condition; as a result, the mapped equation should be re-investigated with a larger number of participants representing a wider range of health conditions.

## 5 Conclusion

This study mapped the EQ-5D-5L and WHOQOL-BREF in the general Thai population using the Thai value set. The study revealed that only the WHOQOL-BREF physical health domain was associated with the EQ-5D-5L index score. An inverse relationship was the best-fit regression model to predict the EQ-5D-5L index score, and the agreement between the observed and predicted EQ-5D-5L index scores was good. The identified minimal impact of difference between the observed and predicted EQ-5D-5L index scores on the ICUR suggests that the health utility score from the herein mapped equation can be utilized in economic analyses. To confirm this finding, further investigation of the mapped equation should be undertaken after including a larger number of participants who represent a wider range of impaired health conditions covering both physical- and psychological-related illnesses.

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## Declarations

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**Conflicts of Interest/Competing Interests** The author declares that he has no competing interests in this study.

**Ethical Approval** This work was approved by the Burapha University Institutional Review Board (BUU-IRB; 108/2562) prior to commencement of the study.

**Consent to Participate** A written consent form was obtained from each study subject prior to commencement of the study; however, all participants were informed that they were able to withdraw from this study at any time if they felt uncomfortable. Moreover, all participants consented to publication of the results of this research.

**Availability of Data and Material** The data analysed and reported in this manuscript are not available for public sharing because all raw data need to be kept with the researcher for privacy in order to comply with ethical standards.

**Code Availability** Not applicable.

**Author Contributions** Krittaphas Kangwanrattanakul was only involved in conception, study design, data collection, data analyses and interpretation, and drafting and final approval of this manuscript.



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