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**Changes in QALYs in Finland
1995/96–2004**



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Abstract

Due to scarce health care resources, knowing the development and incidence of health-related well-being is very important. In this study we contemplate changes in quality adjusted life years (QALYs) in Finland from 1995/96 to 2004. We use three data sets from 1995/96, 2000 and 2004 covering Finnish inhabitants aged 18-79. In calculating QALYs we develop a recursive method and provide QALY changes for undiscounted and discounted scenarios in absolute and *out of attainable* terms. The latter measure, *relative change out of attainable* (RCOA), provides us with more accurate and consistent information about the relation and incidence of changes across age groups and between genders. For health-related quality of life we use an accurate 15 dimensional measure, the 15D, developed by Sintonen (1994,1995). Death probabilities are taken from life tables. The main results establish that QALYs for 18-79 years old females and males have increased in Finland during the period 1995/96-2004. Approximately, 20-60% of the increase is due to increased quality of life, while the rest is due to increased quantity of life. Males are reaching females in life expectancy but the development of the 15D values has been more favourable for females than for males. Use of RCOA to measure the change in the discounted and undiscounted QALYs shows consistently that the incidence of greatest improvements in QALYs is rather for older than for younger inhabitants.

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1 Introduction

In spite of some criticism, the most important health outcome measure is quality adjusted life years (QALYs), which is increasingly used in many developed countries as an outcome measure for health interventions. Thus, QALYs should also be a good candidate for measuring health at the national level.¹ The measure combines length of life with health-related quality of life (HRQoL). At this moment QALYs at the aggregate (population) level have been calculated only in a few countries (e.g. USA, Sweden and Finland) using disparate methods. Except in Finland, the measurement of QALY at the national level has been based on a cruder approach, in which the researchers have developed mappings from other health indicators or disease information than a HRQoL indicator.²

In the current paper we use QALYs to measure the health of the population and its development. Measuring QALYs gives a more precise picture about the development of peoples' health-related well-being than the development of sole life expectancy. Namely, it could be the case that life expectancy had increased while the quality of life had been diminished. Using the plain life expectancy as a measure of health in the described case would imply fallaciously that peoples' health had improved. However, if the quality of life had actually decreased sufficiently, the quality weighted life expectancy would have decreased, signifying decreased health of people. In addition, with QALYs one is able to measure the development of health-related technology, and hence the incidences of the changes in health care through the accurate measure of the quality weights. Finally, measuring QALYs gives a good trajectory to evaluate the health care system and steer health policy in the desired direction.

There are many instruments available for measuring HRQoL and their use varies between countries. There is no golden standard instrument to measure HRQoL but there is some indication that one instrument, namely 15D, is in some respects superior to some other HRQoL measures.³ The properties of the 15D, especially in terms of discriminating power (sensitivity), have been found to be superior to other generally used profile or single index scores instruments.⁴ One important difference between 15D and other measures is its fineness and breadth of coverage of different health

¹One notable caveat with QALY is its implicit assumption about the possibility to distinguish between utility from consumption and health status. If this separation is impossible then so too is the measuring of QALYs. In this paper we however consider that this kind of separation is possible, and hence we omit the mentioned problem.

²See e.g. Cutler and Richardson (1998) and Burström et al. (2001).

³See Sintonen (2001).

⁴For thorough comparison of two multiattribute utility measures, 15-dimensional 15D and 5-dimensional EuroQoL and EQ-TTO, that exposes clearly the strengths of 15D see Stavem (1999).

states; 15D is able to classify 5^{15} different health states with carefully selected 15 dimensions with 5 levels each while e.g. 5-dimensional three-level EuroQoL contains only 3^5 different health states. The 15D has been and is used in many projects for evaluating health technology and has recently been included also in population surveys.⁵

Earlier, Sintonen and Arinen (1997) studied the effects of depression on a quality-of-life measure and on undiscounted QALYs in Finland. They compared expected life years and quality weighted expected life years for 11-year-olds in 1992 and 1995. They found a tendency to increase measures for both health-related quality of life and QALYs. For the whole adult population (≥ 15 years old) the average of the health-related quality-of-life measure increased significantly between 1992 and 1995. In addition, while QALYs increased, the difference in QALYs between genders decreased. Their study however lacks an important viewpoint. Namely, they do not report discounted QALYs and changes, as discounting might have a significant impact on the results and give a somewhat different picture about the incidence of changes, as happened in Cutler and Richardson (1997,1998). They study the development of the value of health in the U.S.A. from 1950-90. As measures they also use life expectancy and QALYs. Quality weights for QALYs are estimated from the data by using self-reported health status and the prevalence of certain diseases. They find that U.S. citizens are healthier than they used to. In the undiscounted case, infants benefit the most while in the discounted case, the elderly have gained clearly more than young citizens. These findings imply that the largest part of improvements has been for the elderly. Along similar lines, Burström et al. (2003) studied the value of the change in health in Sweden for the period from 1980/81 to 1996/97. They estimated discounted QALYs for men and women at specific ages by combining survival rates and health state scores. Age-specific health state scores were estimated by mapping responses to selected survey questions in the Swedish Survey of Living Conditions to the EQ-5D; the UK EQ-5D index tariff is then used to obtain health state scores. Their findings imply that results are again affected by discounting; the incidence of QALY improvements were shown to be favorable for the infants in the undiscounted case while older people have gained the most in the discounted case.

This paper extends the recent research in many respects. Firstly, we estimate QALYs by using a very accurate HRQoL instrument, 15D, which is available in all the data sets for the study. This enables us to contemplate which dimensions of health are the most important and effective

⁵See e.g. Arinen et al. (1998), Aromaa and Koskinen eds. (2004), Räsänen et al. (2006), and Kautto (2006) and further references therein.

in explaining the developments in QALYs. Secondly, we explore the effect of discounting on the distribution of QALYs and the incidence of QALY-changes in the population. Thirdly, we develop and use a measure that we call *relative change out of attainable* (RCOA). That is a measure computed between the realised change in QALYs and the maximum possible change in QALYs given the development of life expectancy. We show that by using RCOA we are able to smooth out the effects of discounting and the constrained 15D measure on the incidence of QALY-changes. Finally, we follow mainly similar lines to Sintonen and Arinen (1997), enabling a comparison of some results, as they also used 15Ds to weight the life years.

The structure for the rest of the paper is as follows: In Section 2 we give a brief overview of the relationship between 15D and QALYs, we use a recursive method with which to compute QALYs, and also introduce the RCOA measure. Section 3 provides a short description of the data, while Section 4 presents the main results. Finally, Section 5 discusses the results and their implications and concludes the study.

2 From 15D to recursively solved QALYs

In this section we give a very brief overview of 15D and QALYs and their relationship. Some counterparts for QALY will also be discussed.

2.1 15D

There are several measures for HRQoL. In the data that are used in the current paper, health-related quality of life is given by the index score of 15 dimensions: mobility, vision, hearing, breathing, sleeping, eating, speech, elimination, usual activities, mental function, discomfort and symptoms, depression, distress, vitality and sexual activity.⁶ The valuation system of the 15D is based on an application of the multi-attribute utility theory.⁷ A set of utility or preference weights, elicited from the general public through a valuation procedure, is used in an additive aggregation formula to generate the 15D score (single index number) over all the dimensions. The maximum score is

⁶For detailed and thorough development and analysis of 15D and its reliability see Sintonen (1994), Sintonen (1995), Sintonen and Arinen (1997) and Sintonen (2001).

⁷In the multi-attribute utility theory the attributes are assumed to be measurable on a ratio scale. Thus, the attributes can be mapped into a common interval, say $[0, 1]$ where 0 represents usually the 'worst' value for the attribute and 1 represents the 'best'. Finally, each attribute gets weight so that when adding up the attributes the weighted sum will be also in the interval $[0, 1]$.

1 (no problems on any dimensions) and the minimum score is 0 (being dead). Formally, the 15D index score has the following representation:

$$v_H = \sum_j I_j(x_j)[w_j(x_j)],$$

where $I_j(x_j)$ is the average relative importance people attach to various levels of dimension j ($j = 1, 2, 3, \dots, 15$), and $w_j(x_j)$ is the average value people place on various levels of dimension j .

2.2 QALY

While HRQoL tells the current state of health-related quality of life, it lacks a time dimension. By taking an expectation of surviving over one year and multiplying it by the expected HRQoL of that particular year one attains a single health-adjusted life year (HALY). Taking a sum of the expected health-adjusted life years (with or without discounting) over life expectancy yields HALYs. Whether quality of life weights are attached to some specific diseases or to health states then defines if the resulting measure is for disease- or quality-adjusted life years, i.e. DALY or QALY, respectively.⁸ QALY is developed to measure overall functional capacity combined with time. In other words, QALY is an aggregated measure of health expectancy.⁹

As we mentioned, the QALY has a representation in the form of a discounted (or an undiscounted) sum of instantaneous utilities where the source of all utility is health status at each time point. The simplest and a general way to present QALY is

$$Q_\tau = \sum_{t \geq \tau} \delta^{t-\tau} u(h_t),$$

where δ is a discount factor, u is a time-independent instantaneous utility function, and h_t is

⁸DALY is developed to measure the burden of a disease, and hence it is a measure of health gap between a perfect health and health with some disease. About the development of DALY and for a thorough analysis about its usage see Murray (1994). For development of QALY see e.g. Torrance (1986). For very thorough analysis of theoretical foundations of QALY see Miyamoto (1999) and Bleichrodt and Miyamoto (2003). For a very recent and interesting refinement of QALY model where extrinsic goals are added to QALY model see Hazen (2007). For careful comparisons and discussions of similarities between HALY, DALY, and QALY see Gold et al. (2002).

⁹In the recent literature the diversity of usage of HALY, DALY, and QALY causes sometimes problems. Due to the similarities in their definitions those are sometimes used interchangeably causing a requirement of high alertness from the reader to be clear what a used definition means formally. E.g. sometimes QALY stands for QALY gain (or loss) while HALE (health adjusted life expectancy) stands for QALY in the sense we described it in here and as it is usually defined.

the health status in period t . In the given representation the utility is simply a product of the time spent in some health state and its quality weight. Hence, by opening up a bit the previous equation we get

$$Q_\tau = \sum_{t \geq \tau} \delta^{t-\tau} V(h)_t,$$

where we have assumed for simplicity that in each period a prevailing health state lasts always through the whole time period, and hence $V(h)_t$ is the quality weight for time period t with the health state h .

2.3 Solving QALYs recursively and RCOA

QALY recursion Denote the variable *age* by a , the *health-related quality of life* for age a by $D(a)$, and the unweighted (i.e. quality-free) life expectation over a single life year by $U(a)$

$$U(a) = 1 - p(a) \int_0^1 s ds = 1 - \frac{p(a)}{2},$$

where $p(a) \in [0, 1]$ is a probability for dying within one year for a person who just turned a years old.¹⁰ Finally, denote a complement of the death probability by $C(a) = 1 - p(a)$, and define $C(T+n) \equiv 0$ for all $n = 0, 1, 2, 3, \dots$, where T is selected as a terminal period so that $p(T+n) = 1$ for all n .¹¹ We then get the following equation for expected QALYs denoted by $Q(a)$

$$Q(a) = U^*(a) + \sum_{i=a+1}^T U^*(i) \prod_{k=a}^{i-1} C(k), \quad (1)$$

where we use an abbreviation $U^*(\cdot) \equiv U(\cdot)D(\cdot)$ while for notational ease discounting is omitted (i.e. $\delta = 1$).¹²

Note now that for any $a < T$ we get from Eq.(1)

$$\begin{aligned} \frac{Q(a) - U^*(a)}{C(a)} &= U^*(a+1) + \sum_{i=a+2}^T U^*(i) \prod_{k=a+1}^{i-1} C(k) \\ &= Q(a+1). \end{aligned}$$

¹⁰We assume that the probability to die within one year is uniformly distributed over the year.

¹¹This is to say that T is the final period over which the expectation is taken.

¹²Note that Eq.(1) is closely related with the QALY equation presented in Sintonen and Arinen (1997) and Sintonen (2000).

Hence,

$$Q(a) = Q(a+1)C(a) + U^*(a), \quad (2)$$

and we are able to solve $Q(a)$ recursively by starting with $Q(T) = U^*(T)$. For a discounted case, it is a trivial task to elaborate Eq.(1) to find out that recursion then takes the following form

$$Q(a) = \delta Q(a+1)C(a) + U^*(a), \quad (3)$$

where δ is the discount factor. The recursions, Eqs.(2) and (3), are the tools we use to compute age group and gender specific QALYs.

To obtain the *attainable* QALYs (i.e. life expectancy) we use Eqs.(2) and (3) by setting $D(a) = 1$ for all a . For the sake of clarity, the attainable QALYs are distinguished from QALYs by denoting it as $L(a)$.¹³

RCOA As one might guess, discounting has a great effect on QALYs and especially on the incidence of their changes. The more (less) the future is discounted the less (more) the expected improvements in the future affect the QALY changes measured from some fixed perspective. Depending on the magnitude of the discount factor used, a comparison of QALY changes from two different perspectives (e.g. two different age groups) can give completely opposite results, as the following example illustrates:

Example 1 Consider a case where a discount factor δ has the value $\frac{1}{2}$, the lifetime is 2 periods, and HRQoLs, i.e. $D(a)$ s, for infants and the elderly depend on the selected policy.¹⁴ Suppose also that an infant has a risk of $p(1) = \frac{1}{10}$ to die at the end of the first period while for the elderly the death is sure at the end of second period, i.e. $p(2) = 1$. The options for the different policies are: (1) HRQoL 1 for period 1 while $\frac{1}{10}$ for period 2, or (2) $\frac{2}{10}$ for period 1 while 1 for period 2. Let's denote the expected QALYs by $Q_{m,z}^n$, where $m \in \{1,2\}$ indicates the policy, $n \in \{i,e\}$ whether the contemplated group is the infant or the elderly group, and $z \in \{u,d\}$ are QALYs undiscounted or discounted. Now, if the social planner does not use discounting and he wants to maximise an infant's expected QALYs he clearly selects policy 2, since it results in $Q_{2,u}^i = 1\frac{1}{10}$, while policy 1

¹³Note that $L(a) \geq Q(a)$ for all a .

¹⁴Naturally, a discount factor of size $\delta = \frac{1}{2}$ is implausible, but in the example it is chosen just to emphasise the difference between discounted and undiscounted cases.

would result in $Q_{1,u}^i = 1\frac{9}{100}$.¹⁵ In contrast, if the social planner uses discounting, he then certainly selects policy 1, since it results in $Q_{1,d}^i = 1\frac{9}{200}$ while policy 2 would result in $Q_{2,d}^i = \frac{130}{200}$ which is clearly less than the QALYs attained through policy 1. If the social planner wanted to maximise QALYs for the elderly he would naturally choose the opposite in the discounted case.

Let us then reinterpret the given policies as two separate time differences in QALYs, i.e. as changes in total expected QALYs from some initial level for two different time intervals 1 and 2. Hence, for the infants the changes are $\Delta Q_{1,u}^i = 1\frac{9}{100}$ and $\Delta Q_{2,u}^i = 1\frac{1}{10}$ in the undiscounted case, while for the discounted case, the changes are $\Delta Q_{1,d}^i = 1\frac{9}{200}$ and $\Delta Q_{2,d}^i = \frac{130}{200}$; for the elderly the respective changes would then be $\Delta Q_{1,z}^e = \frac{1}{10}$ and $\Delta Q_{2,z}^e = 1$, $z \in \{u, d\}$. Now, it is clear that when contemplating time interval 1, one can consistently say that the greatest incidence of QALY change is for the infants no matter whether discounting is used or not. In contrast, when contemplating the QALY incidence for time interval 2 there is no consistent claim about QALY incidence across the infants and elderly but for the undiscounted case one would argue that the infants get the most additional QALYs while for the discounted case the claim would be exactly the opposite and in favour of the elderly.

Example 1 exposes clearly the effects and problems of discounting on QALY comparisons. If a social planner must choose which policy is best, discounting causes problems. If a social planner tries to make a comparison of the incidence of QALY changes between two age groups he again faces difficulties with the discounting, since the improvements take place in a distant future and so there is no consistent way to decide whether the identified incidence is correct in the discounted or in the undiscounted case.

To overcome these types of problems, we introduce and later use a *relative change out of attainable* (RCOA) measure to make QALY changes comparable between age groups. Before releasing a formal representation of RCOA we need to define a QALY gain and a *dynamic* QALY loss, as the RCOA will be the fraction of the former from the latter.

The QALY gain is defined normally, i.e. it is the absolute change in QALYs between two separate time points. Formally,

¹⁵ A calculation example for the expected policy payoffs: Policy 2 without discounting yields $(1 - p(1)) (\frac{2}{10} + 1) + p(1) \frac{2}{10} = 1\frac{1}{10}$. The same policy with discounting yields $(1 - p(1)) (\frac{2}{10} + \frac{1}{2}) + p(1) \frac{2}{10} = \frac{130}{200}$.

$$G_{t_1}^{t_2}(a) \equiv Q_{t_2}(a) - Q_{t_1}(a),$$

where $Q_{t_n}(a)$ refers to expected QALYs at time t_n for age group a . In the recent literature a QALY loss is defined as the difference between expected life years and QALYs within the same time frame, so it basically tells the effect of HRQoL on pure life expectancy for some fixed time frame. The standard QALY loss is a practical measure when one wants to know for one time point how much there is a loss in QALYs between reality and *an ideal world* where everybody has HRQoL at its maximum level and hence the QALYs would receive the value of life expectancy. However, when analysing a change of QALYs in time, we consider that the relevant counterpart for the QALY gain is dynamic QALY loss, that is the difference between the life expectancy (the idealistic situation attained to) at time point t_2 and QALYs at time point t_1 .¹⁶ The dynamic QALY loss is thus defined formally as follows.

$$I_{t_1}^{t_2}(a) \equiv L_{t_2}(a) - Q_{t_1}(a), \quad (4)$$

where $L_{t_n}(a)$ refers to expected life years at time t_n for age group a . It is easy to show (just add and subtract Q_{t_2} to/from the left hand side of Def.(4) and rearrange) that actually

$$I_{t_1}^{t_2}(a) = I_{t_2}^{t_2}(a) + G_{t_1}^{t_2}(a),$$

where the dynamic QALY loss is the standard QALY loss at period t_2 added to the QALY gain between periods t_1 and t_2 . So, the dynamic QALY loss tells us how many attainable QALYs exist between time points t_1 and t_2 for a realised development of life expectancy. In other words, the dynamic QALY loss tells us how much the development of HRQoL affects the development of pure life expectancy within some given time interval, hence it tells us how much there is room for a change in QALYs between the ideal world and reality within the given time frame for the observed change in mortality danger. Finally, RCOA is the fraction of the QALY gain from the attainable

¹⁶Recall that expected QALYs is the quality adjusted life expectancy. Since it is reasonable to consider that one of the main targets of the health policy is to get peoples' health related quality of life as high as possible, we call a situation where HRQoL would reach its maximum value 1 '*an idealistic situation attained to*'. In the idealistic situation, QALYs and life expectancies would thus coincide.

QALY change, i.e. from the dynamic QALY loss, and takes the following form

$$R_{t_1}^{t_2}(a) = \frac{G_{t_1}^{t_2}(a)}{I_{t_1}^{t_2}(a)}. \quad (5)$$

ROCA tells us how much, relatively, the QALY gain of age group a is from the maximum change where HRQoL would change from the current value to value 1 for the given changes in mortality danger.¹⁷ With ROCA we get a more uniform and consistent measure for the incidence of the QALY-changes between age groups since it takes into account how much room there is for an actual change in the expected HRQoL. Trying to make QALY incidence comparisons with measures of plain absolute or relative change leads to inconsistent results that depend heavily on a combination of the age group and whether discounting is used or not. Younger age groups are favoured when discounting is not used, since normally there is very little space for them to gain anything from changes in HRQoL in the near future, while there is usually more room for change in the distant future. For the same reason, older age groups are favoured when discounting is used, since younger persons do not gain from the changes in the distant future but the older gain more from the near future changes. To this end, we still elaborate Def.(5) to show how ROCA also smoothes out this discussed effect of discounting.

Opening up $R_{t_1}^{t_2}(a)$ yields for an undiscounted case

$$R_{t_1}^{t_2}(a)_u = \frac{Q_{t_2}(a+1)C_{t_2}(a) + U_{t_2}^*(a) - Q_{t_1}(a+1)C_{t_1}(a) - U_{t_1}^*(a)}{L_{t_2}(a+1)C_{t_2}(a) + U_{t_2}(a) - Q_{t_1}(a+1)C_{t_1}(a) - U_{t_1}^*(a)},$$

and for a discounted case

$$R_{t_1}^{t_2}(a)_d = \frac{Q_{t_2}(a+1)C_{t_2}(a) + \frac{U_{t_2}^*(a)}{\delta} - Q_{t_1}(a+1)C_{t_1}(a) - \frac{U_{t_1}^*(a)}{\delta}}{L_{t_2}(a+1)C_{t_2}(a) + \frac{U_{t_2}(a)}{\delta} - Q_{t_1}(a+1)C_{t_1}(a) - \frac{U_{t_1}^*(a)}{\delta}}.$$

¹⁷Note that $R_{t_1}^{t_2} \in (-\infty, 1]$. One might wonder why the attainable QALYs, i.e. dynamic QALY loss, is computed by using the maximum of HRQoL but the changes in mortality danger, i.e. in life expectancy, are taken as given. Naturally, the attainable QALYs could incorporate some minimum level of mortality danger. That would not, however, make the measure any different from the current but would only complicate the inferences from it. In addition, letting the mortality danger to get some minimum value for the attainable QALYs would only make dynamic QALY loss, denominator, bigger in the Def.(5) and hence the fraction smaller, as the numerator of ROCA would still stay intact. Thus, all the changes in the results would be only quantitative and no qualitative changes would appear. Finally, letting only one parameter to change, *ceteris paribus*, emphasises the effect of the interest and maintains ROCA in such format that no 'apples and oranges' will be compared. This is to say that since the QALY gain tells the change in QALYs for observed changes in HRQoLs for given changes in mortality danger, it is natural to compare it with maximal changes in HRQoLs for the same given changes in mortality danger.

It is now easy to see that the numerators of $R_{t_1}^{t_2}(a)_d$ and $R_{t_1}^{t_2}(a)_u$ differ from each other by

$$\frac{(1 - \delta) (U_{t_2}^*(a) - U_{t_1}^*(a))}{\delta}.$$

For the denominators the respective difference is

$$\frac{(1 - \delta) (U_{t_2}(a) - U_{t_1}^*(a))}{\delta}.$$

These differences are very close to zero for plausible discount factor values (close to one, say $\delta \in [.95, 1]$) and hence the effect of discounting is almost absent in $R(a)_u$ and $R(a)_d$. This is to say that $R(a)_u \approx R(a)_d$ no matter how large the differences¹⁸.

3 Data

To analyse 15D at the population level, we used three separate population surveys, each of them covering the Finnish adult population and having adequate information to compute the 15D¹⁹ The time-frames for surveys were 1995/96, 2000, and 2004. Each data set is an independently and randomly collected cross-section, with study participants ranging in age from 18 to 94 years old with a varying age range between the data sets.²⁰ After dropping individuals with insufficient 15D information from the data, we obtained observation samples of $N_{95/96}=3579$, $N_{00}=6166$, and $N_{04}=2787$, where the subscript refers to the respective time-frame.²¹ To analyse the death probabilities and life expectancy we used life tables provided by Statistics Finland.²² For discounting we used a yearly discount rate $r = .03$, which yields the discount factor $\delta = (1 + r)^{-1} \cong 0.971$.²³

¹⁸Note that the magnitudes of the differences $(U_{t_2}^*(a) - U_{t_1}^*(a))$ and $(U_{t_2}(a) - U_{t_1}^*(a))$ are constrained from below and above, as they can not get out from the interval $[-1, 1]$.

¹⁹The surveys were The Finnish Health Care Survey 1995/96, see Arinen et al. (1998); Health 2000, see Aromaa and Koskinen eds. (2004); and Finnish Wellbeing Survey 2004, see Kautto (2006). We are grateful to Arpo Aromaa for the possibility to use the Health 2000 data in this study.

²⁰The age range that was covered in all data sets and for both genders was 30-79.

²¹It is important to note here that since the oldest persons in all data sets had life expectancy greater than their prevailing age, we used predicted 15D values for those years by regressing 15D values of 50+ years old inhabitants against the age. Formally, we assumed that $D(a) = \psi + \gamma a$ for all $a \in \{b + 1, b + 2, \dots, T\}$, where ψ is constant, γ the regression coefficient, b denotes the oldest person in the data set, and $T - 1$ the assumed final year with death probability below 1. Without loss of generality, we assumed that $T = 100$.

²²See Statistics Finland (2007)

²³The rate for the discount factor was chosen by the current standards in economic evaluations, see e.g. Weinstein (1996) or Gold et al. (1996) and to be equal with used discount rate in Cutler and Richardson (1997,1998), Cutler

| Expected life years (undiscounted) | | | | | | | |
|------------------------------------|--------|---------|------|------|--------------|--------------|--------------|
| Age group | Gender | 1995/96 | 2000 | 2004 | AC 1996-2000 | AC 2000-2004 | AC 1996-2004 |
| 18-29 | Female | 57.2 | . | 59.0 | . | . | 1.8 |
| | Male | 50.4 | . | 52.5 | . | . | 2.1 |
| 30-39 | Female | 46.8 | 47.2 | 48.2 | 0.4 | 1.0 | 1.4 |
| | Male | 40.1 | 41.0 | 42.2 | 0.9 | 1.2 | 2.1 |
| 40-49 | Female | 37.0 | 37.6 | 38.7 | 0.5 | 1.2 | 1.7 |
| | Male | 31.0 | 31.7 | 32.9 | 0.7 | 1.2 | 1.9 |
| 50-59 | Female | 28.5 | 28.9 | 29.9 | 0.4 | 1.0 | 1.3 |
| | Male | 22.9 | 24.0 | 24.6 | 1.1 | 0.6 | 1.7 |
| 60-69 | Female | 19.0 | 20.0 | 20.9 | 1.0 | 0.9 | 1.9 |
| | Male | 15.1 | 16.2 | 17.2 | 1.1 | 1.0 | 2.1 |
| 70-79 | Female | 11.7 | 12.3 | 13.0 | 0.5 | 0.7 | 1.2 |
| | Male | 9.3 | 10.1 | 10.7 | 0.7 | 0.6 | 1.4 |
| 80-89 | Female | 6.5 | 6.4 | . | -0.1 | . | . |
| | Male | 5.1 | 5.6 | . | 0.4 | . | . |
| 90+ | Female | 2.5 | 3.0 | . | 0.6 | . | . |
| | Male | . | 2.6 | . | . | . | . |

| Expected life years (discounted) | | | | | | | |
|----------------------------------|--------|---------|------|------|--------------|--------------|--------------|
| Age group | Gender | 1995/96 | 2000 | 2004 | AC 1996-2000 | AC 2000-2004 | AC 1996-2004 |
| 18-29 | Female | 27.5 | . | 27.8 | . | . | 0.3 |
| | Male | 25.8 | . | 26.3 | . | . | 0.5 |
| 30-39 | Female | 25.1 | 25.2 | 25.5 | 0.1 | 0.3 | 0.3 |
| | Male | 23.0 | 23.3 | 23.6 | 0.3 | 0.3 | 0.6 |
| 40-49 | Female | 22.2 | 22.4 | 22.7 | 0.2 | 0.4 | 0.5 |
| | Male | 19.7 | 20.0 | 20.4 | 0.3 | 0.4 | 0.7 |
| 50-59 | Female | 18.9 | 19.1 | 19.5 | 0.2 | 0.4 | 0.6 |
| | Male | 16.1 | 16.6 | 16.9 | 0.5 | 0.3 | 0.8 |
| 60-69 | Female | 14.2 | 14.8 | 15.2 | 0.6 | 0.5 | 1.1 |
| | Male | 11.7 | 12.4 | 13.0 | 0.7 | 0.6 | 1.3 |
| 70-79 | Female | 9.6 | 10.0 | 10.5 | 0.4 | 0.5 | 0.8 |
| | Male | 7.9 | 8.4 | 8.9 | 0.5 | 0.5 | 1.0 |
| 80-89 | Female | 5.8 | 5.7 | . | -0.1 | . | . |
| | Male | 4.7 | 5.0 | . | 0.4 | . | . |
| 90+ | Female | 2.4 | 2.9 | . | 0.5 | . | . |
| | Male | . | 2.4 | . | . | . | . |

Table 1: The change in expected life years. Notation: Absolute change (AC).

4 Results

There are two key factors that affect the expected QALYs: i) the hazard rates and ii) HRQoL. In this section we report their changes as well as changes in QALYs. We start by reporting changes in expected life years and then analyse the changes in the 15D values, with finally a careful inspection of the change in the expected QALYs. We give results for the gender-specific age groups: 18 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69, 70 – 79, 80 – 89, 90+.

Expected life years For Table 1 we have computed undiscounted and discounted expected life years for both genders. The absolute change of the respective variable is also present. It is reasonable to note here that expected life years are equal with the attainable QALYs. Hence from the table we see also the change in attainable QALYs.

From the table we see that expected life years have increased in almost all age groups for all time, and for both genders. On average and for the both discounted and undiscounted cases, the time interval 1996 – 2000 has been more favorable for inhabitants aged 50+ years, while 2000 – 2004 has been more favourable for younger inhabitants.²⁴ As a total, in the undiscounted case, the change is decreasing in age for females and almost constant in age for males. In the discounted case we have

et al. (2006), and Burnström et al. (2003) to keep some comparability with their results.

²⁴Even though 1995/96 data set is combined from years 1995 and 1996, the fraction of 1995 individuals is so small that, for convenience, we attach 1996 hazard rate values for all individuals in the data 1995/96.

a slightly different result, as the change is increasing in age for both genders. In all age groups, males are approaching females as the change has been systematically greater for males than for females. The change in expected life years varies between 1.2 – 1.9 and 1.4 – 2.1 for females and males respectively in the undiscounted case. In the discounted case, the respective variations are between .3 – 1.1 and .5 – 1.3 respectively. Hence, there has been a tendency for increased expected life years and a diminished gap between expected life years for the genders.²⁵

15D values Age- and gender-grouped average 15D values and their changes are collated in Table 2. In the table there is a blank for those age group-year combinations that we did not have adequate information on to compute the respective value from the data.

| Average 15D values | | | | | | | |
|--------------------|--------|---------|------|------|--------------|--------------|--------------|
| Age group | Gender | 1995/96 | 2000 | 2004 | AC 1996-2000 | AC 2000-2004 | AC 1996-2004 |
| 18-29 | Female | 0.97 | . | 0.95 | . | . | -0.01 |
| | Male | 0.97 | . | 0.96 | . | . | -0.01 |
| 30-39 | Female | 0.95 | 0.95 | 0.95 | -0.01 | -0.00 | -0.01 |
| | Male | 0.96 | 0.95 | 0.96 | -0.00 | 0.00 | -0.00 |
| 40-49 | Female | 0.94 | 0.93 | 0.94 | -0.01 | 0.00 | -0.00 |
| | Male | 0.94 | 0.94 | 0.95 | -0.00 | 0.01 | 0.01 |
| 50-59 | Female | 0.90 | 0.91 | 0.92 | 0.01 | 0.00 | 0.02 |
| | Male | 0.89 | 0.91 | 0.92 | 0.02 | 0.01 | 0.03 |
| 60-69 | Female | 0.87 | 0.89 | 0.90 | 0.02 | 0.01 | 0.03 |
| | Male | 0.87 | 0.89 | 0.88 | 0.01 | -0.00 | 0.01 |
| 70-79 | Female | 0.83 | 0.85 | 0.88 | 0.02 | 0.03 | 0.05 |
| | Male | 0.82 | 0.84 | 0.85 | 0.02 | 0.01 | 0.03 |
| 80-89 | Female | 0.74 | 0.75 | . | 0.01 | . | . |
| | Male | 0.79 | 0.76 | . | -0.03 | . | . |
| 90+ | Female | 0.71 | 0.66 | . | -0.05 | . | . |
| | Male | . | 0.68 | . | . | . | . |

Table 2: 15D values and their changes. Notation: Absolute change (AC). Statistically significant changes ($p < .05$) in bold.

The tendency for health-related quality of life development is bidirectional. For females aged 18 – 49 and for males aged 18 – 39 there has been a decrease in 15D values for the period 1995/96 –

²⁵Even though the life expectancy in this study is computed from the data to keep the comparability between the QALYs and expected life years as good as possible, the coverage and weighing of the data is so good that there are only very minimal differences between the life expectancies reported by Statistics Finland and our study.

2000.²⁶ However, the decrease is very small and in addition the decrease has got smaller or changed to an increasing phase during the period 2000 – 2004. For males and females aged 40+ and 50+ respectively the absolute change has been mainly positive and larger in absolute values than in the age groups with decreased 15D values for the period 1995/96 – 2004. It is worth noting that the positive development is almost monotonically increasing in age. For the period 1995/96 – 2004, the positive development has been greater for females than for males, excluding 40 – 59 years old inhabitants, for which the opposite is true. Inhabitants aged 70 – 79 have gained the most from the positive development and females aged 70 – 79 have gained the most of all.

Since the change in 15D values accrue from 15 dimensions, it is interesting to contemplate the changes in specific dimensions. Figure 1 contains information on the dimension-specific 15D average level values for selected age groups and for both genders in 1995/96 and 2004.

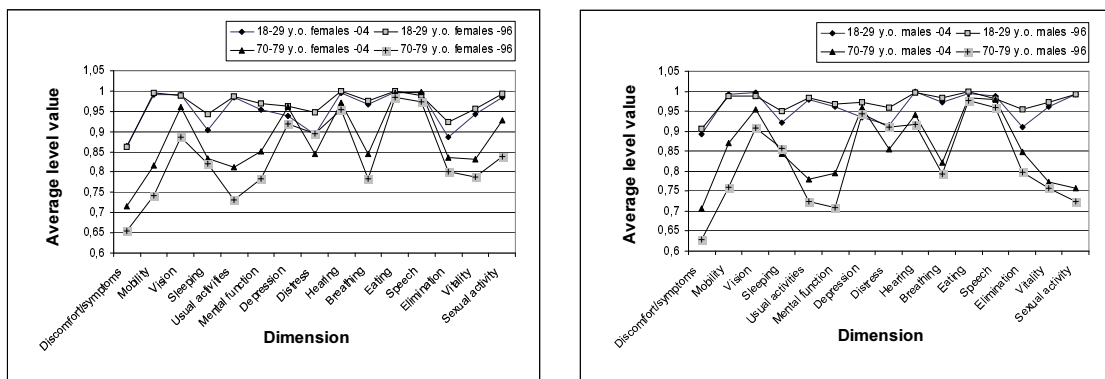


Figure 1: Dimension specific normalised 15D values on 1995/96 and 2004

For females aged 18 – 29 years, 1995/96 has been better or almost the same as 2004 in all dimensions. The biggest negative changes in level values can be found in sleeping, distress, and elimination. For males in the same age group the negative changes were in the same dimensions as females, but the changes were slightly smaller, excluding the change in elimination which was approximately the same. It is notable however that statistically significant ($p < .01$) downward changes for females were found in sleeping, distress, depression and vitality, while for males in the same age group, sleeping did not change significantly.

²⁶The dimension specific exploration below sheds some light on these negative changes and reveals that they might be due to negative changes in distress, sleeping and mental function.

In 2004, inhabitants aged 70 – 79 seem to have greater (or the same) level values in almost all dimensions and for both genders than in 1995/96. In this age group, the biggest improvements can be found in usual activities and sexual activity for females and in mobility and mental functioning for males. For males values in the dimension of distress have been decreasing, while mobility and vision have been increasing statistically significantly ($p < .01$). For females vision, speech, depression and sexual activities have been increasing statistically significantly ($p < .01$). The only decrease in values for both genders can be found in distress, for which the decrease was also statistically significant ($p < .01$).

QALYs QALYs are affected by both changes in expected life years and in 15D values. Together these changes result in the changes in expected QALYs. QALY values, the relative changes out of attainable (RCOA), absolute changes, and decomposed factor effects on absolute change are reported in Table 3 and 4 for the undiscounted and discounted cases, respectively.²⁷

| Undiscounted average QALYs and their changes | | | | | | | | | | |
|--|--------|---------|-------|-------|---------------------------------------|-----------|--------------|--------------|---|-------|
| | | QALYs | | | Relative change out of attainable (%) | | | AC | Decomposed factor effects on AC 1995/96-2004 (%) | |
| Age group | Gender | 1995/96 | 2000 | 2004 | 1995/96-2000 | 2000-2004 | 1995/96-2004 | 1995/96-2004 | 15D | LE/DP |
| 18–29 | Female | 51.24 | . | 54.04 | . | . | 36.05 | 2.80 | 49.22 | 50.78 |
| | Male | 45.84 | . | 48.14 | . | . | 34.34 | 2.31 | 19.77 | 80.23 |
| 30–39 | Female | 41.27 | 41.80 | 43.78 | 8.92 | 30.78 | 36.05 | 2.51 | 43.48 | 56.52 |
| | Male | 35.85 | 36.71 | 38.16 | 16.73 | 26.48 | 36.46 | 2.31 | 24.31 | 75.69 |
| 40–49 | Female | 31.98 | 32.71 | 34.83 | 13.04 | 35.20 | 42.21 | 2.85 | 52.15 | 47.85 |
| | Male | 27.14 | 27.87 | 29.26 | 15.89 | 27.57 | 36.72 | 2.12 | 24.71 | 75.29 |
| 50–59 | Female | 24.06 | 24.61 | 26.58 | 11.42 | 37.53 | 43.47 | 2.52 | 44.08 | 55.92 |
| | Male | 19.61 | 20.62 | 21.38 | 23.05 | 18.97 | 35.36 | 1.77 | 12.19 | 87.81 |
| 60–69 | Female | 15.52 | 16.55 | 18.31 | 22.72 | 40.74 | 52.07 | 2.79 | 48.07 | 51.93 |
| | Male | 12.54 | 13.42 | 14.50 | 23.99 | 28.79 | 42.17 | 1.96 | 25.59 | 74.41 |
| 70–79 | Female | 9.12 | 9.62 | 11.19 | 15.87 | 46.96 | 53.89 | 2.07 | 44.05 | 55.95 |
| | Male | 7.38 | 7.83 | 8.73 | 16.51 | 31.40 | 40.51 | 1.35 | 24.24 | 75.76 |
| 80–89 | Female | 4.71 | 4.62 | . | -5.49 | . | . | . | . | . |
| | Male | 3.98 | 3.94 | . | -2.13 | . | . | . | . | . |
| 90+ | Female | 1.69 | 2.04 | . | 26.19 | . | . | . | . | . |
| | Male | . | 1.67 | . | . | . | . | . | . | . |

Table 3: Undiscounted QALYs. Notation: Absolute change (AC), Life expectancy (LE), Death probability (DP)

²⁷Decomposed factor effects were computed by letting only the 15D to change while keeping the death probabilities on 1996 level, and then the resulting absolute changes were compared with the absolute changes where also death probabilities were changing.

| Discounted average QALYs and their changes | | | | | | | | | | |
|--|--------|---------|-------|-------|---------------------------------------|-----------|--------------|--------------|--|-------|
| | | QALYs | | | Relative change out of attainable (%) | | | AC | Decomposed factor effects on AC 1995/96-2004 (%) | |
| Age group | Gender | 1995/96 | 2000 | 2004 | 1995/96-2000 | 2000-2004 | 1995/96-2004 | 1995/96-2004 | 15D | LE/DP |
| 18-29 | Female | 25.43 | . | 25.90 | . | . | 19.55 | 0.47 | 45.63 | 54.37 |
| | Male | 24.04 | . | 24.62 | . | . | 25.92 | 0.59 | 23.37 | 76.63 |
| 30-39 | Female | 22.79 | 22.91 | 23.44 | 5.12 | 20.46 | 24.15 | 0.65 | 46.43 | 53.57 |
| | Male | 20.96 | 21.29 | 21.79 | 14.47 | 21.62 | 31.47 | 0.83 | 34.40 | 65.60 |
| 40-49 | Female | 19.59 | 19.90 | 20.65 | 10.98 | 26.46 | 33.59 | 1.06 | 59.39 | 40.61 |
| | Male | 17.53 | 17.91 | 18.49 | 15.13 | 22.81 | 32.76 | 0.95 | 35.32 | 64.68 |
| 50-59 | Female | 16.22 | 16.55 | 17.46 | 11.36 | 31.38 | 38.22 | 1.24 | 52.17 | 47.83 |
| | Male | 13.91 | 14.53 | 14.87 | 22.56 | 14.40 | 31.96 | 0.96 | 19.93 | 80.07 |
| 60-69 | Female | 11.73 | 12.37 | 13.41 | 21.42 | 36.39 | 48.17 | 1.69 | 51.48 | 48.52 |
| | Male | 9.82 | 10.43 | 11.06 | 23.65 | 24.48 | 39.00 | 1.24 | 27.43 | 72.57 |
| 70-79 | Female | 7.55 | 7.92 | 9.06 | 15.12 | 44.64 | 51.66 | 1.51 | 46.83 | 53.17 |
| | Male | 6.24 | 6.60 | 7.26 | 16.76 | 29.17 | 38.95 | 1.02 | 27.14 | 72.86 |
| 80-89 | Female | 4.19 | 4.11 | . | -5.30 | . | . | . | . | . |
| | Male | 3.60 | 3.56 | . | -3.03 | . | . | . | . | . |
| 90+ | Female | 1.61 | 1.93 | . | 25.09 | . | . | . | . | . |
| | Male | . | 1.59 | . | . | . | . | . | . | . |

Table 4: Discounted QALYs. Notation: Absolute change (AC), Life expectancy (LE), Death probability (DP)

Let us first contemplate the undiscounted case. For the period 1995/96 – 2004 there is a clear increase in QALYs for both females and males, and for all age groups. Females have gained between 2.07 – 2.85 QALYs while the respective gain for males is between 1.35 – 2.31 QALYs. Even though a clear pattern for age-dependent development is non-existent, there is especially for males a tendency for decreasing positive age-dependent development. That is, for older inhabitants there is a smaller increase than for younger inhabitants.²⁸ Females have gained more QALYs than males in absolute terms in all age groups. Measured with RCOA, the incidence of the QALY improvements is shown in a different light. RCOA shows that older inhabitants have gained more attainable QALYs than younger inhabitants. Males aged 30 – 39 have gained more QALYs than females, while for the rest of males the opposite is true. Finally, an inspection of decomposed factor effects on absolute change reveals that changes in 15D for the period 1995/96 – 2004 cause approximately 40 – 50% of the total QALY changes for females while for males the respective effect of 15D changes is only approximately 10 – 25%. There is no clear age dependent pattern for the factor effects for either

²⁸This feature has a natural explanation when the discount factor is set unity. The changes from the whole life span are now utilised in full expected strength, and hence the more there are expected life years for an individual the greater the sum of improvements in terms of expected QALYs.

gender but there exists very slight tendencies that show the effect of 15D to be increasing in age for females while it is decreasing for males.

Let us then contemplate the discounted case and compare the results with the undiscounted case. We see immediately that there are some changes in the results. For the period 1995/96 – 2004, the absolute change is still positive in all age groups and for both genders, but now the positive change is rather increasing with age. That is, older inhabitants have, in principal, gained more QALYs than younger inhabitants. Males aged 18 – 39 have now gained more QALYs than females, while for inhabitants aged 40+ the opposite is true as measured in either absolute terms or with RCOA. In absolute terms the QALY improvements vary between .47 – 1.69 and .59 – 1.24 for females and males, respectively. Again, decomposed factor effects on absolute change reveal that changes in females' QALY are due to changes in 15D values to a greater extent than for changes in males' QALYs. For females, approximately 45 – 60% of the change in QALY is due to changes in the 15D value while for males the respective interval is approximately 20 – 35% depending on the age group. Again, no clear age-dependent patterns exist for either gender but now the tendencies are reversed. Hence, the effect of 15D is now somewhat increasing in age for males and decreasing for females. Notably, using RCOA to measure the incidence of QALY changes shows consistently in the discounted and undiscounted cases how the elderly have gained more QALYs than younger inhabitants.

It is now interesting to compare the development of expected life years and QALYs. If the changes in QALYs are greater than the changes in expected life years then the QALY loss has diminished.²⁹ A comparison of the results in Table 1 and 3 – 4 shows that in both scenarios, undiscounted and discounted, QALYs have changed clearly more than expected life years in all female age groups. For males, the difference between the changes is smaller but still for inhabitants aged 18 – 59, the QALYs have changed more than expected life years in the undiscounted scenario. In the discounted scenario the result is the same with the exception that for males aged 70 – 79 the QALYs had also changed more than expected life years. In both scenarios, undiscounted and discounted, the difference between the changes has been greater for females than for males. Hence, we can summarise that the QALY loss has mainly diminishing between 1995/96 – 2004 and more

²⁹Recall that expected life years is equivalent with the attainable QALYs and QALY loss is the difference between realised QALY and attainable QALY. To see this use the notation and recall that realised and attainable QALYs in years 1 and 2 are Q_{t_i} and L_{t_i} , $i \in \{1, 2\}$, respectively, and QALY loss $Q_{t_i} - L_{t_i}$ is $I_{t_i}^{t_i}$. Finally, note that $(Q_{t_2} - Q_{t_1}) - (L_{t_2} - L_{t_1}) = (Q_{t_2} - L_{t_2}) - (Q_{t_1} - L_{t_1}) = I_{t_2}^{t_2} - I_{t_1}^{t_1}$ which is our claim.

so for females than for males.

5 Discussion and conclusion

In this study we have found that 18–79-year-old Finnish people were doing somewhat better in 2004 than nearly ten years previously in 1995/96 in terms of health-related attributes. Both the quality and quantity of life have increased. As a consequence, the quality adjusted life years of 18–79-year-old females and males have increased steadily between 1995/96 and 2004. Approximately 20–60% of the increase is due to increased health-related quality of life, measured with the 15D, while the rest is due to increased life expectancy, i.e. decreased hazard rates. For males, increased life expectancy is to a greater extent the cause for the QALY increase, while for females a positive change in the health-related quality of life causes a notably larger part of the QALY improvements. Males are approaching females in life expectancy but the development of health-related quality of life has been more favourable for females than for males. On average, the gap in QALYs between the genders is growing in favour of females. Use of RCOA to measure the change in QALYs shows in both undiscounted and discounted scenarios that the incidence of greatest improvements in QALYs is rather for older inhabitants than for younger inhabitants in the study. On the other hand, comparisons between the genders within age groups show us that younger males have gained more QALYs than females, while the the opposite is true for older inhabitants.

A comparison of the undiscounted and discounted scenarios reveals clearly that the measure of absolute change is quite sensitive to discounting and gives a somewhat different understanding of QALY gains. RCOA does not suffer from this problem but shows in both cases an increasing path of positive development of QALYs in age. The age-dependent incidence of QALY improvements could also be inferred partially by comparing the absolute changes in the undiscounted and discounted case. Namely, the more the future is discounted, the less the future affects the present value of expected QALYs. On the other hand, in the undiscounted scenario, an individual benefits from the improvements of the whole expected life. Hence, if there are differences in the absolute changes between the undiscounted and discounted scenarios then the improvements are merely local and not distributed uniformly over the age groups. Whether discounting should be used and to what extent, if at all, in QALY calculations is still an open question. Nevertheless, leaning on our results we can say that RCOA gives a more consistent measure about the incidence of QALY improvements

that is less affected by discounting.

At this stage it is reasonable to mention and discuss some caveats and shortcomings of the study. The use of predicted 15D values for those ages in later life for which data is lacking probably overestimates the health-related quality of life for those ages, for the reason that we know health-related quality of life can actually decrease substantially and quickly during the final years of one's life. Hence, due to the use of predicted 15D values, the older the inhabitant the more QALYs are overestimated, especially the discounted ones.

While the assumption about constant 15Ds for later life overestimates QALYs, there are also three important factors that might underestimate QALYs and their changes. Firstly, the use of cohort specific 15D values and life tables as the basis for expectations about future life tables and 15Ds underestimates the development of QALYs. That is, in the computations of expected QALYs we consider that an individual who is x years old in cohort X meets after z years the same 15D value and hazard rates that an individual who is $x + z$ years old has in year X . As we have seen, 15Ds and life expectancies are getting mostly greater with time. Thus, an assumption of a 30-year-old inhabitant having, for example, at the age of 50 in 2016 the same values for 15D and death probabilities as 50-year-old inhabitants in 1996 is rather naive and presumably underestimates QALYs.³⁰ Secondly, we do not control the effect of marginal survivors on 15D averages. This can decrease QALYs since it is plausible to argue that a marginal survivors have a lower than average 15D, and hence, if they did not survive, the 15D average for respective age group would be higher as well as increase the QALYs. Finally, the data we used does not include inpatients from institutional care. Due to recent developments in health care practice, there were many outpatients in 2004 who would have been inpatients in 1996.³¹ It is quite obvious that 15D values for inpatients are lower than average. Thus, including those who would have been inpatients in 1996 into the data for 2004 pushes the 15D averages down, and in this sense the change is milder than what it would have been if the system had stayed the same between 1996 and 2004.

It is hard to know which of the mentioned effect dominates, but we believe that our QALY estimates are rather underestimated than overestimated.

³⁰However, we adopt the ideology from Cutler et al. (2006) and we think that using the life tables in a static way, that is as they were the same in the future, gives a good picture of current wellbeing throughout all the age groups. One way to think this is to consider it as a *ceteris paribus* - assumption, if everything stick to same we would be able to maintain the expected QALYs with the current system.

³¹For the changes in health care practice for elderly see e.g. OSF and Social Protection (2007).

Even though we did not have adequate information about 15Ds for inhabitants aged younger than 18, we wanted to understand the magnitude of their QALY changes and make some comparisons. Hence, to compute their QALYs and changes we assumed that 15D for ages 0 – 17 has a maximum value.³² On this basis, an infant male showed an increase in QALYs from 68.4 to 70.7 without discounting, a total increase of 2.3 QALYs. and with discounting an increase from 28.9 to 29.1, a total increase of 0.2 QALYs. For females the respective approximations were an increase from 74.4 to 77.0 resulting in an increase of 2.6 QALYs without discounting, and an increase from 29.6 to 29.8 and an increase of 0.2 QALYs with discounting. The gap between infant males and females remains intact with discounting, while without discounting it increases in favour of females. This reflects that the greatest improvements are in the distant future, especially for females. The claim gets even more strength when comparing these QALY-changes with QALY-changes for the elderly. We found that for 70 – 79 years old, the increase in undiscounted QALYs has been approximately 1.35 and 2.05 for males and females, respectively. With discounting, the respective increases in QALYs were still 1 and 1.5. These comparisons clearly corroborate the main findings of the study, that changes in QALYs have been more favourable for the elderly than for younger inhabitants.

Comparing our results with Sintonen and Arinen (1997) reveals that the development of QALYs in Finland has changed recently. Sintonen and Arinen (1997) found that for the time period 1992 to 1995, inhabitants aged 11 showed a 2.2 and 0.7 improvement of undiscounted QALYs for Finnish males and females, respectively. Their findings imply a decreasing QALY-gap between females and males, whereas in our study the approximated difference between the genders for a newborn shows to be in favour of females.³³ According to our findings the gap has also been increasing in almost all other age groups in favour of females, measured both in absolute terms and with RCOA. This observed switch in development of QALYs can be mostly explained by the better developed HRQoL of females. We saw that around 20% of male and more than 50% female QALY-changes were due to positive development in 15D and that this development was more or less equal throughout the

³²This can be reasoned at least from two different perspectives. Firstly, the dimensions in 15D incorporate such attributes, e.g. sexual activity, for which the correct level would be hard if not possible to define for 0 – 17 years old individuals. Secondly, to obey observed interaction between age and HRQoL it is plausible to assume that on average 15D for 0 – 17 years old individuals is very close to 1 as it seems to be so for 18 – 29 years old individuals as well. Hence we conclude that assuming 1 as 15D value for them is less incorrect and makes less harm than assuming some arbitrary value below of it.

³³For 11 years old the changes in QALYs as well as the gap between the genders should be almost the same with infants as the hazard rate for 0-15 years old is very close to 0 and changes in it are almost absent. Hence, the loose comparison that we are doing here between QALYs of 11 years old Finnish inhabitants of Sintonen and Arinen (1997) study and estimated QALYs of infants in our study should be fair.

age groups. Sintonen and Arinen (1997) for their part emphasise that especially for males the improvements in both HRQoL and life expectancy are the very reason for the QALY improvements between 1992 and 1995. So, our findings reflect that the positive development of male HRQoL for this period did not continue between 1995/6 and 2004, even though life expectancy has still continued its fairly positive development. Making use of very thorough HRQoL-weight listings provided in Tengs and Wallace (2000) we can still speculate about which health care practices have led to observed changes in QALYs. We found that distress has been increasing throughout the age groups. Tengs and Wallace (2000) report a substantially larger impact of mental diseases on QALYs, hence the increase in depression could be a consequence of policies that have been amplified outpatient care and decreased inpatient care in mental diseases. According to Tengs and Wallace (2000), HRQoL-weight listings for cardiovascular and orthopedic diseases are significantly effecting QALYs. In Finland, these are exactly the diseases for which treatment is increasing in older patients. Cardiovascular and orthopedic diseases effect an individual's functional capacity and living in many ways. Receiving treatment for those diseases can improve one's mobility, breathing, usual activities and sexual activity. As patients with cardiovascular and orthopedic diseases are to a large extent the elderly, the greatest gains from amplified treatments should be also be found among the elderly. This is exactly what we have found.

The cost-benefit literature values life in monetary terms. This has also inspired users of cost-effectiveness analysis to express QALY units in monetary terms. The monetary value for a QALY unit is necessary, otherwise the cost-effectiveness analysis falls short in saying anything about whether an intervention should be implemented or not on economic grounds. To establish the benefit from an intervention, a monetary value is assigned to a QALY to make the outcome comparable to its costs in monetary terms. By using the value of \$100 000 per QALY, we find that the health capital has been increasing by \$230 000 or \$20 000 for infant males and \$260 000 or \$20 000 for infant females, depending respectively on whether discounting is applied or not.³⁴ Even though the time frames in Cutler and Richardson's (1997, 1998) study on health development in the U.S.A. and Burström et al.'s (2003) study on health development in Sweden are not the same as in our

³⁴There is no standard or consensus about the correct monetary value for a QALY unit. For a vast discussion about the value of life and its measuring see Viscusi (1993). About defining a value for a QALY unit see e.g. Johannesson and Meltzer (1998). The value of \$100 000 per QALY unit has been used among other several studies also in Cutler and Richardson (1997,1998) and Burström et al. (2003) and hence we use the same value to maintain some comparability with their results.

study, we find it interesting to make international comparison about the development of health capital. We find that an infant Finn in 1996 has had almost \$500 000 greater health capital than an infant in the U.S.A. in 1990. On the other hand, the health capital has been increasing at a slower speed in Finland for the period 1995/96 – 2004 than in the U.S.A. for the period 1980 – 1990. According to our approximation, an infant Finn has gained \$20 000 in health capital during the period 1995/96 – 2004, while an infant in the U.S.A. has gained almost \$50 000 during the period 1980 – 1990. When comparing Swedish and Finnish health capital and its development, we find that health capital has been developing more favourably in Finland than in Sweden for both genders. The health capital for a Finnish infant male was \$180 000 greater than an infant Swedish male in 1996/97. The respective difference for females was even greater with a \$350 000 difference in favour of Finnish females. Interestingly, the development of health capital in Sweden during the period 1987/88 – 1996/97 has been different from the Finnish development for 1994/95 – 2004. Infant Swedish males have lost \$12 600 in health capital, while females have lost \$88 000 in health capital during the given time frames.

Finally, in the light of our findings we can conclude that the positive improvements in HRQoL for females in Finland have recently outweighed the better development of life expectancy for males, as their HRQoL has not been developing as much as for females, while the development of life expectancy has remained quite benign also for females. As we have seen, even small changes in different dimensions of 15D reveal clearly how QALYs are developing over time. With other less accurate HRQoL measures, these findings would not have been possible. In addition, since we are collecting accurate and systematic death rates of the population so as to analyse the development of life expectancy over time, there is no sound reason to omit a systematic collection of accurately measured HRQoL, namely 15D, for the population. Only by doing so are we able to give precise estimations of the development of the health state of the population combined with its life expectancy, which is necessary for allocating scarce health care resources efficiently and appropriately. Moreover, since health capital is increasing and there are substantial differences between countries, we should find an increase of and international differences in the demand for health and life insurance. Whether this is the case or not is, however, beyond the scope of this paper and remains to be explored in the future. Future research topics that spring naturally from the current research include the allocation of health care resources, its optimisation, and connecting these with the costs of public health care. Finally, health care practice evolves constantly and hence we should

be aware of how increases in the frequency of some treatments and decreases of other treatments affect population's QALYs as a result of different policy implementations. Hence, adequate data is very important to continued research on the effects of specific treatments on specific HRQoL dimensions and also their effects on QALYs.

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