MAFEIP

Support Services for the Management and Utilization of Monitoring and Assessment of the EIP - MAFEIP Tool

Kinesis QTUG™

Authors:
Barry Greene, Seamus Small, Clara Faulí, Ruth Vilar, Strahil Birov, Veli Stroetmann, Francisco Lupiáñez-Villanueva

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Executive summary

Description of the intervention

Kinesis QTUG™[1] is a medical device that assesses an older adults' falls risk, frailty and mobility with the objective to facilitate the accurate and early identification of patients at risk of falling. This would allow for a timely intervention, which could reduce the incidence of fall-related injury and its associated costs (Greene et al., 2016)[2]. QTUG automatically analyses patients' data and compares it with the reference values for the patient's age and gender. It is based on the Timed Up and Go test (TUG) and it is instrumented with wireless inertial sensors[3]. This method was tested in Dublin (Ireland) as part of TRIL, a large ageing research project. The assessment targeted community dwelling adults aged 60 years and older. Results showed that the accuracy of this combined method was 68.5%. This value was 66.8% for a method using sensor data alone, and 58.5% when only clinical data was used (Greene et al., 2016). QTUG is a registered Class I medical device in Europe, the United States, Canada and Australia and is being commercialised by Kinesis Health Technologies Ltd[4].

Model input

Defining the health states and the transition probabilities

The main outcome variable are falls, since the goal of QTUG is to prevent them. The deteriorated state includes those individuals that have fallen at least once during the year, while people in the baseline state have not experienced any fall. According to the scientific literature, around 33% of people aged 60s fall each year (Greene et al., 2016; Masud & Morris, 2001[5]; WHO, 2007[6]), which represents the incidence rate for the control group. The application of interventions after the QTUG assessment could decrease the risk of falling, in consequence, the incidence rate for the intervention group is reduced to 24.2%. The recovery rate refers to the probability of not falling (concretely for those that fell in the previous period), which is *1-Incidence rate.* Therefore, the rate would be 67% for the control group and 75.8% for the intervention group. Since falls are one of the main causes of accidental death and disability in older adults (Masud & Morris, 2001; WHO, 2007), the risk for mortality of those that have fallen should be a bit higher. Thus, a relative risk of 1.373 is applied for the deteriorated health state (Boehler, Graaf, Steuten, Abadie, & Pecchia, 2015)[7], for both the control and intervention groups (Table 1).

Computing the costs

The costs of the intervention include the expenditure related to the QTUG assessment and to the subsequent intervention for those detected as *potential fallers*. The cost of using the Kinesis

[1] /www.kinesishealthtech.com/QTUG
[2] Greene, B. R., Redmond, S. J., & Caulfield, B. (2016). Fall risk assessment through automatic combination of clinical fall risk factors and body-worn sensor data. IEEE J. Biomed Health Inform 2016. 21(3). DOI: 10.1109/JBHI.2016.2539098
[3] http://www.kinesis.ie/
[4] http://www.kinesis.ie/
[5] Masud, T., & Morris, R. O. (2001). Epidemiology of Falls. Age and Ageing, 30(S4), 3–7.
[6] WHO. (2007). WHO Global Report on Falls Prevention in Older Age. France: World Health Organization 2007.
[7] Boehler, C., Graaf, G. De, Steuten, L., Abadie, F., & Pecchia, L. (2015). Using the EIP on AHA monitoring tool for the early technology assessment of a planned device to predict falls in the elderly. Seville: European Commission - Joint Research Centre (JRC).

QTUG device is €5 per person and year, the cost of the personnel who perform the test is around €15, and the cost of the intervention €450, which is multiplied by the percentage of individuals who would receive the intervention (34.9%). The overall intervention costs per patient and year are €177.05. Healthcare costs related to falls depend on their severity. The cost per fall is estimated to be €8,582.27, while the cost per fall hospitalisation raises to €26,310.18. Since the literature found that 20% of falls result in serious injury (Alexander, Rivara, & Wolf, 1992[8]; Sterling, O'Connor, & Bonadies, 2001[9]), which is the percentage of falls requiring hospitalisation, the expected cost of a patient that has fallen (deteriorated state) is €12,128. Patients in the baseline state have not fallen, hence, the healthcare cost is 0 (Table 1). We assume that the intervention does not have a direct effect on healthcare costs, thus, we apply the same values for the control and intervention groups. The project did not assess the societal costs related to falls, so societal costs are equivalent to healthcare costs (Table 1).

Utility

Thiem et al. (2014) investigated the relationship between falls and EQ-5D rated quality of life and found that the EQ-5D score of the individuals that did not report any fall was on average 81.1, while that of those that fell at least once was 77.0. We use these values for the present exercise, but converting them to the 0-1 range. We assume that the intervention does not have a direct effect on individuals' utility, thus, the same values are used for the control and intervention groups (Table 1).

Table 1. Input data used to populate the MAFEIP model

	Control Group	Intervention Group
Transition Probabilities		
Incidence	33 %	24.2 %
Recovery	67 %	75.8%
Relative Risk		
Baseline State	1.00	1.00
Deteriorated State	1.373	1.373
Costs		
One-off cost per patient (Intervention)	-	0 €
Recurring cost per patient/year (intervention)	-	177,05€
Healthcare cost – Baseline	0 €	0 €
Healthcare cost – Deteriorated	12,128 €	12,128 €
Societal cost – Baseline	0 €	0 €
Societal cost – Deteriorated	12,128 €	12,128 €
Utility		
Baseline State	0.81	0.81
Deteriorated State	0.77	0.77

Model output

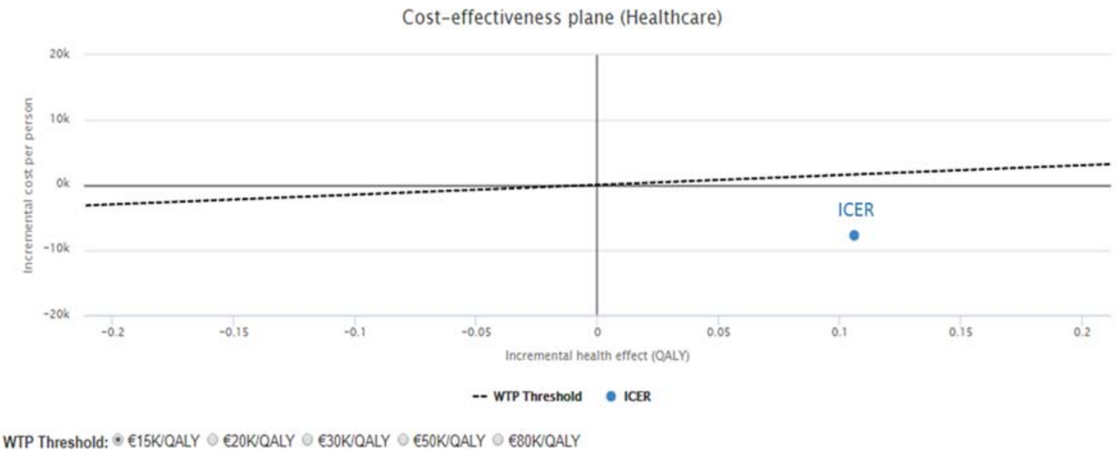
Figure 1 shows the overall impact of the intervention on the costs and effects of the whole target population. It displays the incremental cost-effectiveness ratio (ICER)[10], which is placed in the

[8] Alexander, B. H., Rivara, F. P., & Wolf, M. E. (1992). The cost and frequency of hospitalization for fall-related injuries in older adults. American Journal of Public Health, 82(7), 1020–1023.
[9] Sterling, D. A., O'Connor, J. A., & Bonadies, J. (2001). Geriatric Falls: Injury Severity Is High and Disproportionate to Mechanism. The Journal of Trauma: Injury, Infection, and Critical Care, 50(1), 116–119.
[10] This is the ratio between incremental costs and incremental effects.

lower-right quadrant. Thus, the intervention is dominant (i.e. both cheaper and more effective than usual care), and it would be acceptable to implement it.

Figure 1. Cost-effectiveness

Incremental cost and HRQoL effects	
Incremental cost (Healthcare)	-7760.83
Incremental effects	0.106
Incremental cost-effectiveness ratio (Healthcare)	Dominant



1. Description of the intervention

Kinesis QTUG™[11] is a medical device that assesses an older adults' falls risk, frailty and mobility. The objective is to facilitate the accurate and early identification of patients at risk of falling. This would allow for a timely intervention. That could reduce the incidence of fall-related injury and its associated costs (Greene et al., 2016)[12]. Avoiding falls is a key intervention for older adults, since they are the one of the main causes of accidental death, disability, injury, and hospitalisation (Greene et al., 2016; Masud & Morris, 2001; WHO, 2007). In current care this fall risk is usually assessed by a variety of specialists: physical therapists, geriatric specialists, and community nurses or occupational therapists. There are several clinical tools available to assess this risk, but they usually require the expertise of a healthcare specialist (Greene et al., 2016). Therefore, the existence of an objective tool that could be used by non-specialists like QTUG, would free up specialists' time, who could focus on investigating the factors related to the risk of falling, and, afterwards, these specialists, physiotherapists or exercise professionals could perform interventions to reduce this risk (Greene et al., 2016).

QTUG automatically analyses patients' data and compares it with the reference values for the patient's age and gender. The most relevant data is shown in the summary results screen and deviations from normality are highlighted with specific colours. It also provides a falls risk score, a statistical estimate of a patients' risk of having a fall[13]. QTUG is based on the Timed Up and Go test (TUG) and it is instrumented with wireless inertial sensors placed on each of the patient's legs[14]. The TUG test is a commonly used standard test of mobility that covers standing, sitting, walking and turning. The test records the time that an individual spends in getting up from a chair, walking three metres, turning through 180º at a designated spot, returning to the seat and sitting back down. The results in this test have been associated with falling (the longer time, the higher probability of falling), but the test alone is only moderately accurate in assessing fall risk (Greene et al., 2016). QTUG is a registered Class I medical device in Europe, the United States, Canada and Australia and is being commercialised by Kinesis Health Technologies Ltd[15].

This method was tested in Dublin (Ireland) as part of TRIL, a large ageing research project. The assessment targeted community dwelling adults aged 60 years and older (the mean was 73.6 years), except those with history of stroke and those unable to walk without assistance (Greene et al., 2016). The number of participants was 748, coming from two separate waves (616 people in the first wave and 132 in the second). However, complete sensor data was available for 422 individuals, which were the ones included in the analysis. The assessment took place in St James's Hospital (SJH) and was performed by clinical staff. During this assessment, inertial sensors captured movement data during the Timed Up and Go (TUG) test using the QTUG software (Greene et al., 2016). Moreover, this data was combined with a clinical risk factor based fall risk assessment. Results showed that the accuracy[16] of this combined method was 68.5%. This value was 66.8% for a method using sensor data alone, and 58.5% when only clinical data was used

[11] /www.kinesishealthtech.com/QTUG
[12] Greene, B. R., Redmond, S. J., & Caulfield, B. (2016). Fall risk assessment through automatic combination of clinical fall risk factors and body-worn sensor data. IEEE J. Biomed Health Inform 2016. 21(3). DOI: 10.1109/JBHI.2016.2539098
[13] /www.kinesishealthtech.com/QTUG
[14] http://www.kinesis.ie/
[15] http://www.kinesis.ie/
[16] This is the percentage of subjects correctly classified by the algorithm as being a 'faller' or 'non-faller'

(Greene et al., 2016). The study had a retrospective design that used cross-sectional data on fall history.

In addition, an analysis on costs performed[17]. This compared the use of QTUG to detect potential fallers and implement preventive interventions for them, with a situation in which no intervention to prevent falls was applied. It was based in a scenario with 1,000 patients and it used the sensitivity[18] values from the first wave, which were 66.99 for the QTUG (combined method), 72.82 for sensor data alone, and 46.81 for clinical data alone (Greene et al., 2016).

2. Model input

2.1. Defining the health states and the transition probabilities

The main outcome variable are falls, since the goal of QTUG is to prevent them. The deteriorated state includes those individuals that have fallen at least once during the year, while people in the baseline state have not experienced any fall. According to the scientific literature, around **33%** of people aged 60s fall each year (Greene et al., 2016; Masud & Morris, 2001[19]; WHO, 2007[20]), which represents the **incidence rate** for the control group. This implies that in a scenario with 1,000 patients 330 of them would fall. According to the sensitivity values reported above, 221 (66.99%) would be correctly identified by QTUG. Based on reviews of randomised trials of interventions to reduce falls, it is estimated that an intervention could reduce falls by around 30-50% , 40% is chosen here for convenience (El-Khoury, Cassou, Charles, & Dargent-Molina, 2015; Gillespie et al., 2012). Therefore, if an intervention was implemented for the potential fallers identified, only 60% of them would fall (133). Adding them to those that the device would not identify (109) gives a total number of fallers of 242. Thus, the incidence rate for the intervention group is **24.2%.** This comprises the number of fallers not identified by QTUG and the number of fallers identified by the tool but for which the intervention did not avoid the fall.

The **recovery rate** refers to the probability of not falling for those that fell in the previous period, who would then move from the deteriorated state (fall) to the baseline health state (no fall). Since we have two possible outcomes (fall/no fall[21]), the probability of not falling is *1-Incidence rate,* which would be **67%** for the control group and **75.8%** for the intervention group. Nonetheless, we must keep in mind that the history of falling is a risk factor for future falls (Greene et al., 2016; Tromp et al., 2001[22]). Thus, the probability of falling among patients in the deteriorated health state could be higher than among those in the baseline. However, this would affect both the intervention and control groups.

As mentioned above, falls are one of the main causes of accidental death and disability in older adults (Masud & Morris, 2001; WHO, 2007). Therefore, the **risk for mortality** of those that have fallen should be a bit higher. A relative risk of **1.373** is applied for the deteriorated health state (Boehler, Graaf, Steuten, Abadie, & Pecchia, 2015)[23]. The relative risk of the baseline health is 1,

[17] http://www.kinesis.ie/QTUG_cost_calculator.html
[18] This is the percentage of the fallers identified correctly
[19] Masud, T., & Morris, R. O. (2001). Epidemiology of Falls. Age and Ageing, 30(S4), 3–7.
[20] WHO. (2007). WHO Global Report on Falls Prevention in Older Age. France: World Health Organization 2007.
[21] There is a third possible outcome, dying. But this is covered by the *Relative risks for mortality* parameters.
[22] Tromp, A. M., Pluijm, S. M. F., Smit, J. H., Deeg, D. J. H., Bouter, L. M., & Lips, P. (2001). Fall-risk screening test: a prospective study on predictors for falls in community dwelling elderly. Journal of Clinical Epidemiology, 54, 837–844.
[23] Boehler, C., Graaf, G. De, Steuten, L., Abadie, F., & Pecchia, L. (2015). Using the EIP on AHA monitoring tool for the early technology assessment of a planned device to predict falls in the elderly. Seville: European Commission - Joint Research Centre (JRC).

since they have not fallen and, thus, they have the same risk than the general population in this age range. It is not clear whether the intervention had a direct impact on mortality (other than through the reduction in the probability of falling). Thus, we apply the same values for the control and intervention groups.

2.2. Computing the costs

The costs of the intervention include the expenditure related to the QTUG assessment and to the subsequent intervention for those detected as *potential fallers*. The first element comprises the cost of using the Kinesis QTUG device (**€5**), and the cost of the personnel who perform the test (**€15**)[24]. On the other hand, the intervention's cost is estimated to be €450 per patient, which account for 10 hours of work of the physiotherapist, rehabilitation specialist, or similar professional. This is aimed only at those detected as *potential fallers*. Thus, for those not identified under this label, the cost is 0. As mentioned in the previous section, 221 potential fallers out of the total number of patients (1,000) would be correctly identified. Moreover, the specificity[25] value for QTUG is 80.95 (Greene et al., 2016), implying that there would be 128 false positives. Therefore, 349 individuals would receive the intervention, this is a 34.9%. Multiplying this value by the cost of the intervention (€450), we obtain an expected cost per patient of **€157.05**. Thus, as can be seen in Table 2, the overall intervention costs per patient and year are **€177.05**.

Table 2. Intervention costs

Intervention costs (per patient and year)	
Cost of using the Kinesis QTUG device	€5
Cost of the personnel performing the test	€15
Cost of the intervention	€157.05
TOTAL costs	€177.05

Healthcare costs related to falls depend on their severity. The cost per fall is estimated to be US $9,643, while the cost per fall hospitalisation raises to US $29,562 (Burns, Stevens, & Lee, 2016)[26]. These are €8,582.27 and €26,310.18 respectively[27]. On the other hand, the literature found that 20% of falls result in serious injury (Alexander, Rivara, & Wolf, 1992[28]; Sterling, O'Connor, & Bonadies, 2001[29]). This is the percentage of falls requiring hospitalisation. Therefore, the expected cost of a patient that has fallen (deteriorated state) is **€12,128**[30]. Patients in the baseline state have not fallen, hence, this value is 0 (Table 3). We assume that the intervention does not have a direct effect on healthcare costs (apart from the fact that it decreases the probability of falling), since once an individual has fallen, the same costs are incurred whether the person had been assessed by QTUG or not. Consequently, we apply the same values for the control and intervention groups. The project did not assess the societal costs related to falls, so societal costs are equivalent to healthcare costs.

[24] This refers to 20 minutes of time at a rate of €45 per hour for personnel
[25] This is the percentage of the non- fallers correctly identified
[26] Burns, E. R., Stevens, J. A., & Lee, R. (2016). The direct costs of fatal and non-fatal falls among older adults- United States. Journal of Safety Research, 58, 99–103.
[27] Exchange rate 1$=0.89€ (23 June 2017)
[28] Alexander, B. H., Rivara, F. P., & Wolf, M. E. (1992). The cost and frequency of hospitalization for fall-related injuries in older adults. American Journal of Public Health, 82(7), 1020–1023.
[29] Sterling, D. A., O'Connor, J. A., & Bonadies, J. (2001). Geriatric Falls: Injury Severity Is High and Disproportionate to Mechanism. The Journal of Trauma: Injury, Infection, and Critical Care, 50(1), 116–119.
[30] The cost per fall (8,582.27) multiplied by 0.8 plus the cost per fall hospitalisation (26,310.18) multiplied by 0.2

Table 3. Healthcare Costs (per patient and year in €)

Control Group baseline health	
Cost related to falls	0
Cost related hospitalisation due to falls	0
Total	0
Control Group deteriorated health	
Cost related to falls	6,866
Cost related hospitalisation due to falls	5,262
Total	12,128
Intervention Group baseline health	
Cost related to falls	0
Cost related hospitalisation due to falls	0
Total	0
Intervention Group deteriorated health	
Cost related to falls	6,866
Cost related hospitalisation due to falls	5,262
Total	12,128

2.3. Utility

Utility of those that have fallen is lower than those that have not, since there is a negative association between falls and lower EQ-5D rated quality of life. Falls can bring several negative consequences such as fall-related injuries (e.g. fractures), reduced physical activity, fear of falling again, impairments in quality of life, etc. (Thiem et al., 2014)[31]. Thiem et al. (2014) investigated the relationship between falls and EQ-5D rated quality of life among German community-dwelling seniors. Their results revealed that the EQ-5D score of the individuals that did not report any fall was on average 81.1, while that of those that fell at least once was 77.0. We use these values for the present exercise, but converting them to the 0-1 range.

We presume that the intervention does not have a direct effect on individuals' utility (apart from the fact that it influences the probability of falling). This implies assuming that if they do not fall, patients' quality of life is the same regardless of whether they followed an intervention or not. The same applies for those that have fallen: if they fall their utility decreases by the same amount if they received an intervention and if they did not. Therefore, the same values are used for the control and intervention groups.

Table 4. Utility

	Control	Intervention
Baseline	0.81	0.81
Deteriorated	0.77	0.77

[31] Thiem, U., Klaaßen-Mielke, R., Trampisch, U., Moschny, A., Pientka, L., & Hinrichs, T. (2014). Falls and EQ-5D rated quality of life in community-dwelling seniors with concurrent chronic diseases: a cross-sectional study. Health and Quality of Life Outcomes, 12, 2.

3. Model output

Figure 2 shows the incremental costs for every age-gender combination. Incremental costs refer to the difference between the cost that a person from a specific age and gender would have if he/she spent all the life course in intervention minus the cost that would have if he/she followed current care. This value depends on the cost of the intervention, the cost associated with each alive health state (baseline, deteriorated) and the probabilities of staying in each of them for both situations (intervention and control). In the present case, incremental costs are negative, implying that the intervention is cheaper than the usual care alternative. This is a result of successfully decreasing the incidence of falls. For the older age groups, the values are closer to 0, meaning that savings are smaller.

Figure 3 shows the incremental effects by age that compare the effects, calculated in terms of quality-adjusted life years (QALYs), for each age-gender combination in the intervention and control groups. They are positive, showing that the intervention managed to increase individuals' quality of life, even though only slightly.

Both figures show incremental costs and effects discounted at an annual discount rate of 4% (lines labelled as "Discounted") or without applying any discount rate (lines labelled as "Undiscounted").

Figure 2. Incremental cost by age

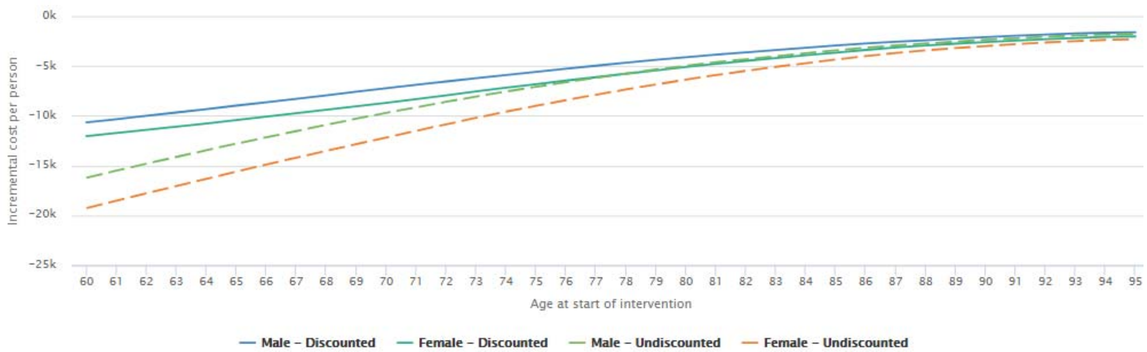
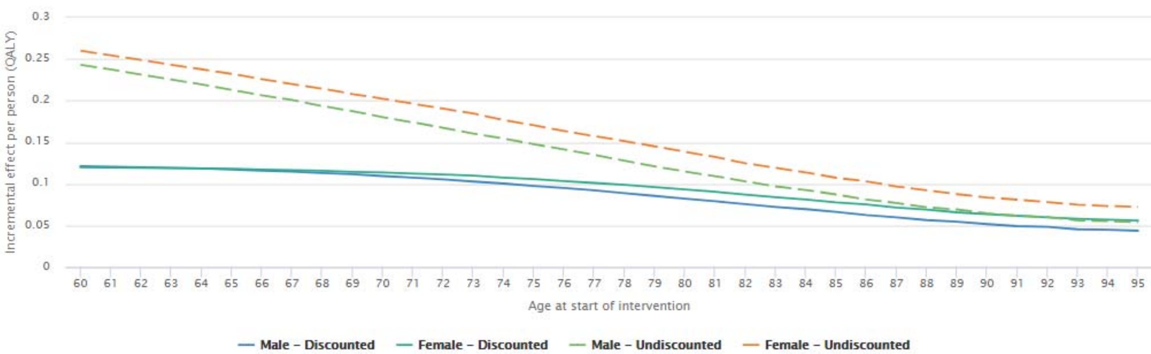


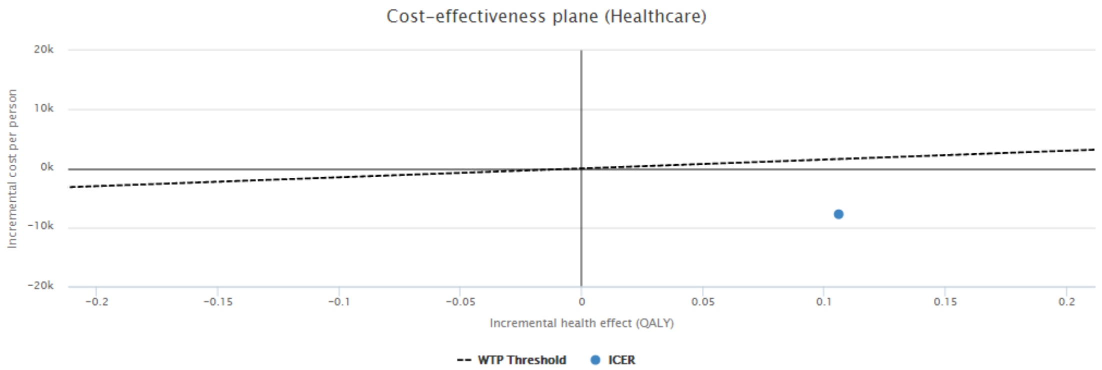
Figure 3. Incremental effects by age



The cost-effectiveness plan, shown in Figure 4, presents the overall impact of the intervention on healthcare costs and QALYs for the total target population. The values show the average per-patient, which is weighted by the age-gender distribution in the target country. The horizontal axis displays the incremental health effects (QALYs) and the vertical the incremental costs. The blue dot is the incremental cost-effectiveness ratio (ICER), the ratio between incremental costs and incremental effects, and the diagonal line represents the willingness to pay (WTP) per additional QALY gained. In this case, the ICER lies in the lower-right quadrant, which means that the intervention is dominant (i.e. it is both cheaper and more effective than usual care). In consequence, it would be acceptable to implement it.

Figure 4. Cost-effectiveness plane (healthcare costs)

Incremental cost and HRQoL effects	
Incremental cost (Healthcare)	-7760.83
Incremental effects	0.106
Incremental cost-effectiveness ratio (Healthcare)	Dominant



WTP Threshold: ◉ €15K/QALY ○ €20K/QALY ○ €30K/QALY ○ €50K/QALY ○ €80K/QALY

The following figures show the cumulative costs and effects accumulated over the model time horizon for the whole population, concretely for 1,359,581 people, the population 60 or older in London[32]. The figures display the cumulative values for the first year when the intervention is implemented and for the subsequent years. The cumulative impact at the population level in the long-term would be 10.5 Billion € saved and 144,032 QALY gained. Looking at the discounted values[33], we observe that the main gains in terms of savings and quality of life occur during the first twenty years. Afterwards, the lines are practically flat, meaning that the additional gains are rather small.

[32] Data for the UKI Region. Eurostat, population on 1 January by age group, sex and NUTS 3 region [demo_r_pjangrp3] (2016)
[33] The discount rate is 4% for both costs and effects.

Figure 5. Cumulative incremental costs

Population-level impact	Population: 1359581 Reset
Population-level impact on incremental cost (Healthcare)	-10551478730.07
Population-level impact on incremental HRQoL	144032.06

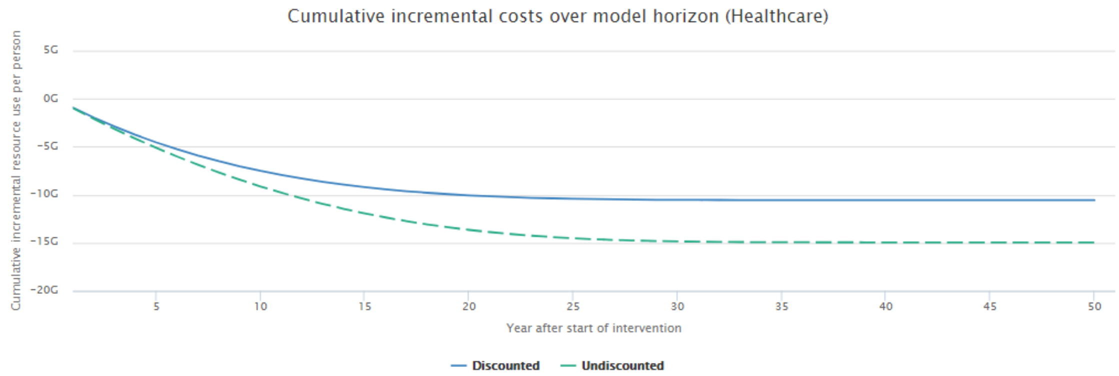
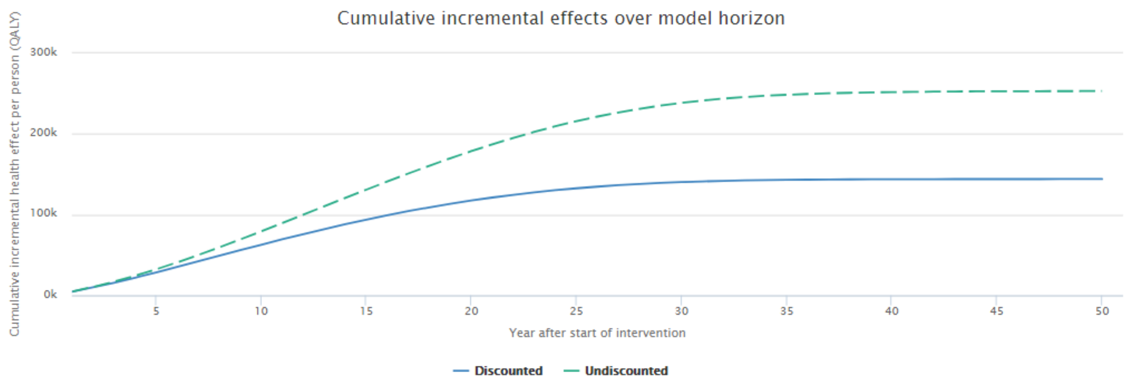


Figure 6. Cumulative incremental effects



The figures below display the expected transition between states for one specific person (here a 60 year old female). Regarding the transition between alive states, the patient has a higher probability of maintaining baseline health if she belongs to the intervention group (dashed line in green). This is due to the fact that the intervention group has lower incidence rate and higher recovery rate. On the other hand, the probability of dying is almost the same for both groups (Figure 8).

Figure 7. Patient flow through model states (Alive states)

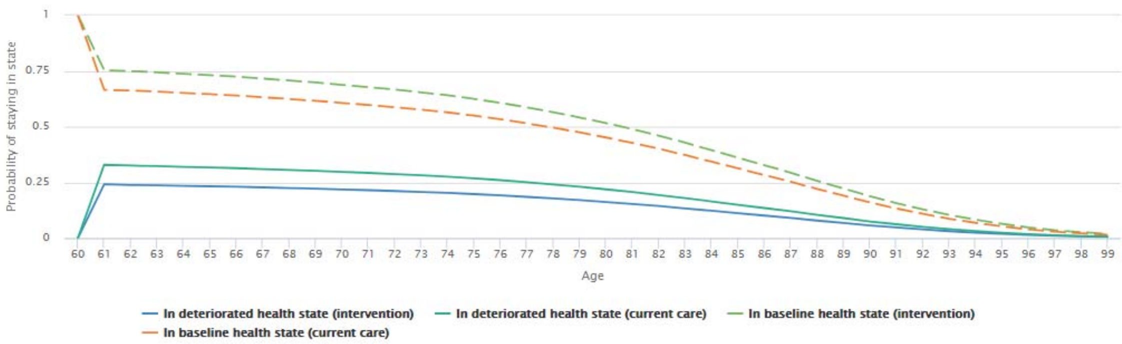
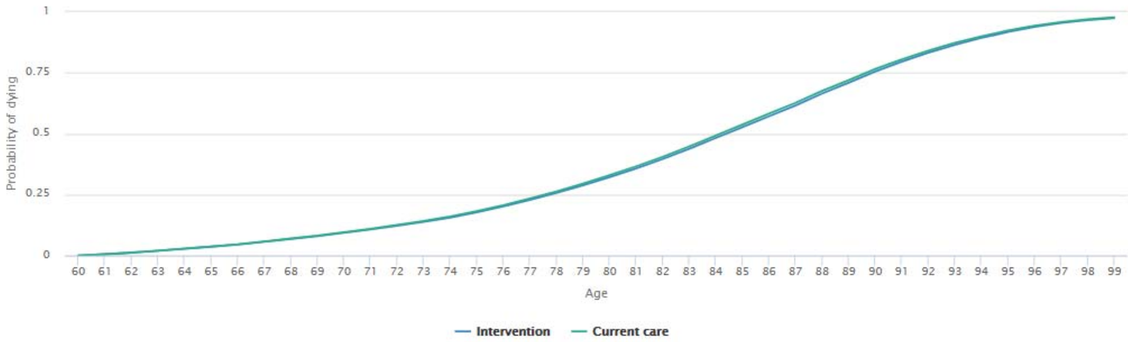
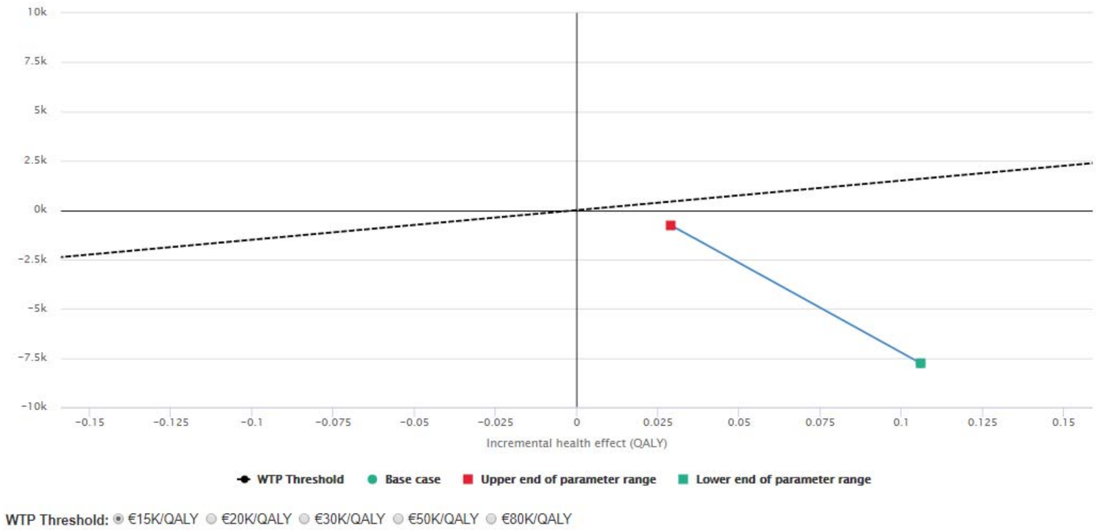


Figure 8. Patient flow through model states (Dead state)



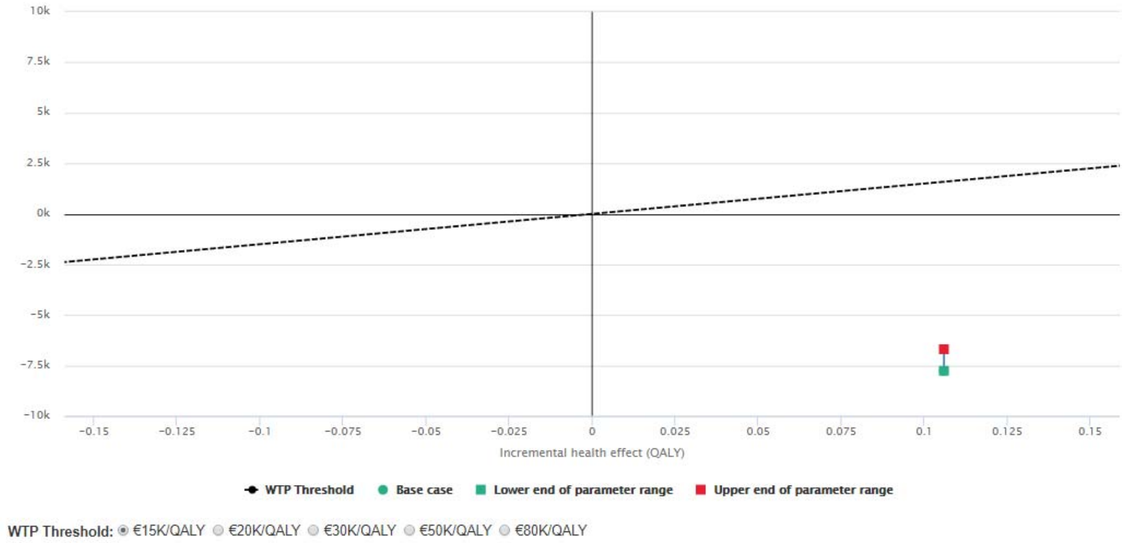
The sensitivity analysis assesses the impact of changes in selected parameters on the outcome of the evaluation, using a univariate deterministic sensitivity analysis[34]. In Figure 9 we see what would happen if the intervention was less efficient in reducing the incidence of falls. As the incidence rate increases, savings and incremental effects of the intervention decrease when compared to usual care. However, when the incidence rate is at the highest point (red square), which represents the point where incidence rates are the same for intervention and usual care, the intervention is still dominant. This is due to the fact that we only changed the incidence rate parameter, while the recovery rate remains higher for the intervention. If we increase the discount rate for costs (from 4% to 6%), we see that savings decrease a bit (Figure 10).

Figure 9. Univariate sensitivity analysis with an increase in the incidence rate for the intervention group



[34] All parameters are varied one-by-one over a specified range of input values.

Figure 10. Univariate sensitivity analysis with a change in discount factor for costs



The figures below show to what extent a ±10% change in several parameters affects the incremental costs (Figure 11) and the incremental effects (Figure 12). The parameter that most affects the incremental costs are the healthcare costs for the control group in the deteriorated state. A 10% change in this element would increase or decrease incremental costs by more than 3.5 Million € per patient for the whole time horizon. On the other hand, the utility of baseline health for the intervention group has a higher impact on incremental effects, followed by the same parameter for the control group. A 10% increase in the utility associated with the baseline health state in the intervention would imply an increase of 0.650 QALYs per patient.

Figure 11. Parameter impact on incremental costs

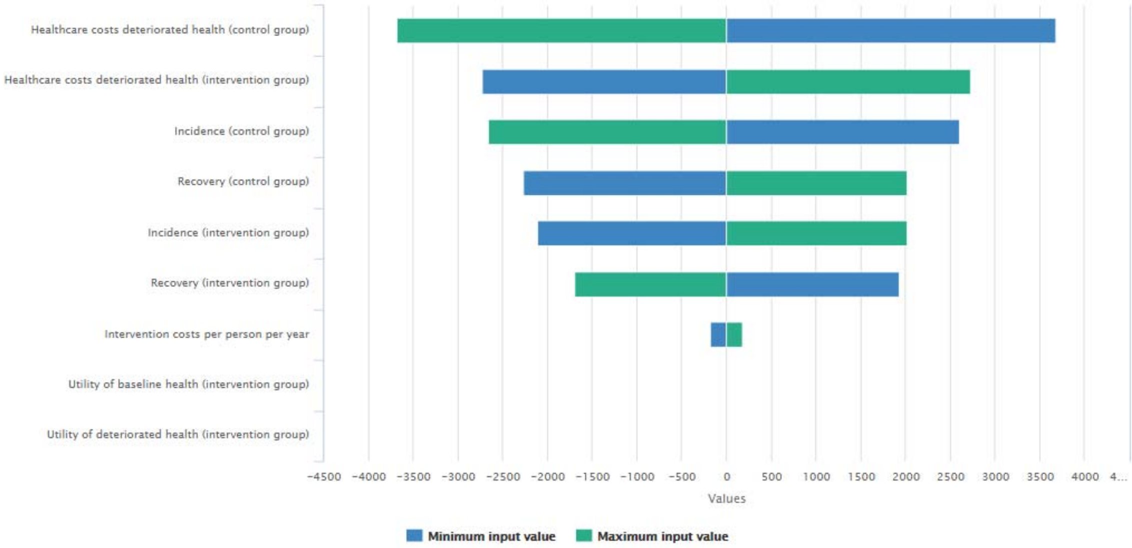
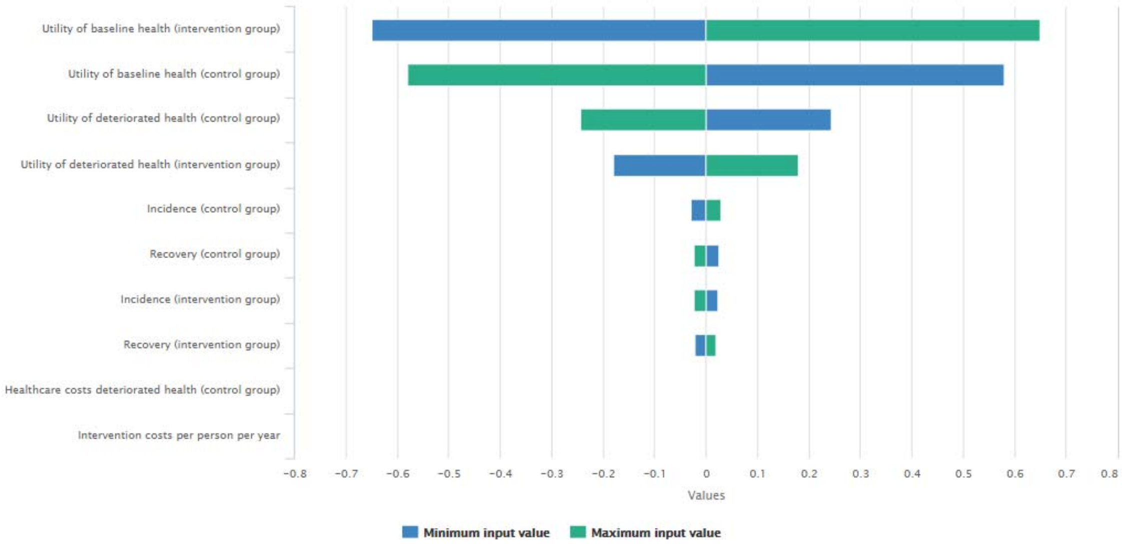


Figure 12. Parameter impact on incremental effects



4. Lessons learned

This section summarises the main difficulties we have encountered in adapting the QTUG intervention to the Markov model used in MAFEIP. These difficulties are detailed below:

- In the MAFEIP tool all participants start in the baseline state, which implies that participants have not fallen in the previous period. However, this does not adapt to reality, where there are people that did fall in the preceding year.
- The intervention after the QTUG assessment was not aimed at all patients but only at those identified as *potential fallers*. In order to take this into account, the cost of the intervention was multiplied by the proportion of individuals that had been identified.
- Some costs were in $ (since they were obtained from the scientific literature), and they had to be converted to €.

These lessons learned can be applied for the further development of the MAFEIP tool.