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The cost-effectiveness of an updated theory-based online health behavior intervention for new university students: U@Uni2

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The transition to university marks a point where young people may be open to changing health behaviours such as smoking, exercise, diet and alcohol intake. This study aimed to estimate the cost-effectiveness of an updated online health behaviour intervention for new university students in the UK – "U@Uni2", compared with both a control (measurement only) scenario and with the original intervention ("U@Uni1"). The economic analysis, based on a randomized controlled trial, comprised a detailed costing analysis, a within-trial cost-effectiveness analysis and long-term economic modelling. Cost-effectiveness of the U@Uni2 trial was estimated using 6-month data on costs and health-related quality of life. An individual patient simulation model was adapted for long-term economic analysis of U@Uni2. Probabilistic sensitivity analysis and value of information analysis accounted for uncertainty in model inputs and identified key parameters. The U@Uni2 intervention costs £45.97 per person for full implementation, £10.43 per person for roll-out in a different institution and £3.03 per person for roll-out over five years. The U@Uni2 trial was not cost-effective because marginally fewer quality-adjusted life years (QALYs) were obtained in the intervention arm than the control. However, modelled over a lifetime, U@Uni2 is estimated to produce more QALYs than control but fewer than U@Uni1, primarily due to the effect of the interventions on smoking. Roll-out of U@Uni2 is highly likely to be more cost-effective than doing nothing (ICER = £536 per QALY, 86% probability cost-effective). Decision uncertainty occurs primarily around the effectiveness of the U@Uni2 intervention and is worth up to £3.24 m. The U@Uni2 intervention is highly likely to be cost-effective to roll-out when compared with doing nothing. The results suggest that preventing uptake of smoking is the key driver of QALY gain and should be the primary target of such interventions.

Key words: Alcohol, diet, exercise, smoking, health behavior, cost-effectiveness, economic evaluation, students, university.

INTRODUCTION

The National Health Service (NHS) spends billions of pounds per year treating the burden of disease caused by unhealthy lifestyle choices such as smoking, excessive drinking, lack of exercise and poor diet (The King's Fund,

2014). Many of these behaviours are adopted early in adulthood, and ultimately result in an increased risk of disease and mortality, and a reduction in health-related quality-of-life. The transition between school and university is a point when individuals are likely to change existing health behaviours and establish new habits (Friedman et al., 2008; Plotnikoff et al., 2015). U@Uni is an online intervention based upon the psychological theories of self-affirmation, planned behaviour and implementation intentions (Ajzen, 2005; Gollwitzer and Sheeran, 2006; Harris and Epton, 2009), which targets four health behaviours: smoking, drinking alcohol, eating fruit and vegetables, and physical activity in new university students. A 2012 randomized clinical trial (RCT) of a first variant U@Uni1 and a full economic analysis of U@Uni1 versus 'measurement only' control concluded that although the effect of the intervention on health behaviours was small, rolling out the intervention to other universities would be cost-effective (Epton et al., 2014; Kruger et al., 2014).

The U@Uni1 trial suffered from low levels of recruitment and technological problems, resulting in poor engagement with the intervention. An updated version of the intervention (U@Uni2) was designed using the LifeGuide intervention software developed by Southampton University (Yang et al., 2009), which helped to minimize technical problems. The pre-intervention baseline questionnaire was also shortened. The U@Uni2 intervention was compared with the control in an RCT of 2,623 undergraduates beginning their studies in 2013 at the University of Sheffield, United Kingdom. Results from the trial are available elsewhere (Cameron et al., 2015).

This economic evaluation aims to estimate the short-term (6-month) and long-term (lifetime) cost-effectiveness of U@Uni2, when compared with both the 'measurement only' control condition and also with the U@Uni1 intervention. The perspective of the study is that of the UK Department of Health.

METHODS

The economic evaluation took the same format as U@Uni1 (Kruger et al., 2014), with three components: a costing analysis; a within-trial analysis; and an economic modelling analysis to estimate long-term cost-effectiveness of the U@Uni2 intervention, when compared with either the control condition or with the U@Uni1 intervention. The methods are summarized here; detailed methods are available in the online supplementary appendix.

Costing analysis

The costs of U@Uni2 were estimated using a modified version of theU@Uni1 staff costs questionnaire (Kruger et al., 2014 and Additional file 1). Staff from the Department of Psychology were asked to estimate the number of hours they had spent developing, updating and implementing the U@Uni2 intervention in addition to any non-staff costs incurred. The full economic cost of all staff time including overheads, national insurance and pension costs was estimated using the University of Sheffield's University Research Management System. Costs were calculated at 2013 values. Three different scenarios were costed for long-term modelling. The cost of full implementation of a U@Uni2 style intervention including development costs, the cost for roll-out of the existing U@Uni2 intervention to another university, and the cost of rolling out the intervention assuming it could be used for five years with minimal updating (five-year costs). Roll-out costs were estimated in a similar manner by including the cost of developing local elements from U@Uni1 in addition to a subset of costs from U@Uni2. Five-year costs were based upon roll-out costs but were divided into an annuitized set-up cost and an annual maintenance cost. The long-term economic modelling allows three-way comparison of control, U@Uni1 and U@Uni2 interventions. To allow direct comparison, all costs from U@Uni1 were inflated to 2013 values using the consumer price index from the Office of National Statistics (ONS) (Office for National Statistics, 2014).

Within-trial cost-effectiveness analysis (short-term 6-month time horizon)

A within-trial analysis was performed by balancing the gain in QALYs accrued during the trial against the cost of healthcare and the costs of full implementation of the U@Uni2 intervention. Healthcare costs were calculated from questionnaire data that asked about healthcare utilisation during the trial period (Cameron et al., 2015). NHS Reference Costs 2012-13 (Department of Health, 2013) and the Unit Costs of Health and Social Care 2013 (Personal Social Service Research Unit, 2013) were used to assign unit costs to each healthcare source used. Data on health-related quality of life was collected at baseline, one month and six month time-points, and weighted using preference based EQ-5D values (Dolan et al., 1995). Missing data for costs and health-related quality of life was imputed using multiple imputation by chained equations (White et al., 2011). Baseline characteristics of the individuals who took part in the trial are presented in Appendix Table 1. Ordinary least squares (OLS) regression models were generated to estimate total costs and QALYs using personal characteristics as covariates.

Long-term economic modelling (lifetime time horizon)

Long-term cost-effectiveness of the U@Uni2 intervention was assessed using an adaptation of the U@Uni1 economic model (Kruger et al., 2014). The model is a population based individual patient-level simulation that models individuals selected from baseline data collected in the U@Uni2 trial. Their age, gender, portions of fruit/vegetables consumed daily, units of alcohol consumed weekly, minutes of physical activity undertaken weekly and smoking status influence their probability of dying and their estimated utility during each year of their life. The same individuals were simulated in control conditions and with the U@Uni1 and U@Uni2 interventions. Life years, QALYs and costs were discounted annually at 1.5% as recommended by NICE for public health economic evaluations (National Institute for Health and Clinical Excellence, 2012). Incremental analysis was carried out to

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compare each of the interventions with the control condition and with each other.

Uncertainty

Probabilistic sensitivity analysis (PSA) was carried out to estimate the probability of the interventions being cost-effective at different willingness to pay thresholds. 30,000 model runs were performed, each simulating 1000 random individuals. Expected value of perfect information (EVPI) and partial expected value of perfect information (EVPPI) were carried out, using the Sheffield Accelerated Value of Information (SAVI) online tool (Strong et al., 2014), to determine the value of further research into parameter estimation.

A series of structural sensitivity analyses were carried out to test certain model assumptions. The sensitivity of the results of the duration of intervention effect was tested by fixing the mean at values of 1, 2, 5 and 10 years. The model was also tested for the sensitivity of results to the structural updates to the model. Finally, the contribution of each of the four individual behaviors to costs and QALYs was assessed.

RESULTS

Costing analysis results

Costs for full implementation of the U@Uni2 intervention were estimated at £61,828 (£50,544 to £73,158, 95% confidence interval [CI]), of which £47,179 was due to previous spending on U@Uni1 and £14,649 was specific to U@Uni2. Staff cost was £27,444 in total, whilst non-staff costs comprised £34,384. This is considerably cheaper than the cost estimated for full implementation of U@Uni1 (Kruger et al., 2014), which when inflated to 2013 values came to £213,921. The reason for the large difference is due predominantly to the use of the LifeGuide software for U@Uni2 (Yang et al., 2009), which eliminated the need for costly development of a website from scratch. Given that there were 1,345 individuals in the intervention arm of the RCT, this works out as £45.97 per person (£37.58 to £54.39, 95% CI).

Roll-out costs for U@Uni2 were estimated at £15,701 (£13,555 to £17,864, 95% CI), of which £9,792 was due to previous spending on U@Uni1 and £5,909 was specific to U@Uni2. The comparable inflated costs for U@Uni1 were £30,768. The U@Uni1 costs were larger due to website maintenance that the U@Uni1 site required. The mean number of UCAS acceptances per UK institution in 2013 was 1,506 (Universities and Colleges Admissions Service, 2013). Dividing U@Uni2 roll-out costs by this figure results in a cost of £10.43 per person (£9.00 to £11.86, 95% CI).

The costs of rolling out U@Uni2 over a five year period were estimated as £4,563 per year (£3,842-£5,292, 95% CI), of which £2,946 was due to annuitized setting up costs and £1,617 was yearly maintenance costs. This was equivalent to £3.03 per student (£2.55 to £3.51, 95% CI). Comparable inflated costs for U@Uni1 were £9,434 (£8,530-£11,234, 95% CI), of which £6,069 was due to annuitized setting up costs and £3,365 was yearly maintenance costs. This worked out as £6.26 (£5.66 to £7.46, 95% CI) per person.

Within-trial cost-effectiveness analysis results

The within-trial analysis found that the U@Uni2 intervention cost an extra £35.30 (£30 to £40.51, 95% CI, based on 5000 bootstrap runs) per individual when compared with the control arm, considerably lower than the incremental costs generated in the intervention arm of the U@Uni1 trial (£326.37). The incremental cost was entirely due to the cost of the intervention, as healthcare utilization was reduced in the intervention arm of the trial, resulting in lower healthcare costs when compared with the control arm (-£10.67). Although, the intervention group used fewer healthcare resources during the 6-month trial period, they also gained fewer QALYs than the control group (-0.0025 incremental QALYs), although this was not statistically significant (0.0001 to -0.0051, 95% CI, based on 5000 bootstrap runs).

The incremental cost-effectiveness ratio (ICER) was calculated at -£14,314 per QALY gained (at a threshold of £20,000 per QALY). INB was found to be -£84.63, indicating that the intervention is not cost-effective in the short-term, due to the negative estimated QALY gain. Uncertainty analysis determined that the probability the intervention would be cost-effective at this threshold is only 0.0004 (Figure 1).

Long-term economic modelling results

The long-term lifetime economic modelling results are presented in detail in **Error! Reference source not found.** and Figure 2. Both U@Uni1 and U@Uni2 produce small increases in life years and QALYs gained as compared to the control. However, U@Uni2 is slightly less effective than U@Uni1, producing only 0.00533 incremental QALYs when compared with the 0.00767 incremental QALYs produced by U@Uni1.

Incremental costs for full implementation of U@Uni2 when compared with control are £37.90, resulting in an ICER of £7,106, an INB of £69 and a probability cost-effective of 76% (Tables 1 and Figure 2). In contrast, incremental costs for full implementation of U@Uni1 are £152.94. The intervention is marginally cost-effective with an ICER of £19,947, but there is a high level of uncertainty around this result as the probability cost-effective is only 49%. Direct comparison indicates that the updated U@Uni2 intervention is more likely to be cost-effective than the original U@Uni1 intervention, with a probability of 75% and INB of £68 (Table 1).

Roll-out of U@Uni2 costs only £2.86 per person, when compared with £9.26 for roll-out of U@Uni1. Both interventions are likely to be cost-effective in the roll-out scenario when compared with control to a similar extent (ICER = £1,207 for U@Uni1, probability cost-effective =93%; ICER = £536 for U@Uni2, probability cost-effective = 86%) (Table 1 and Figure 2). Despite higher costs, the

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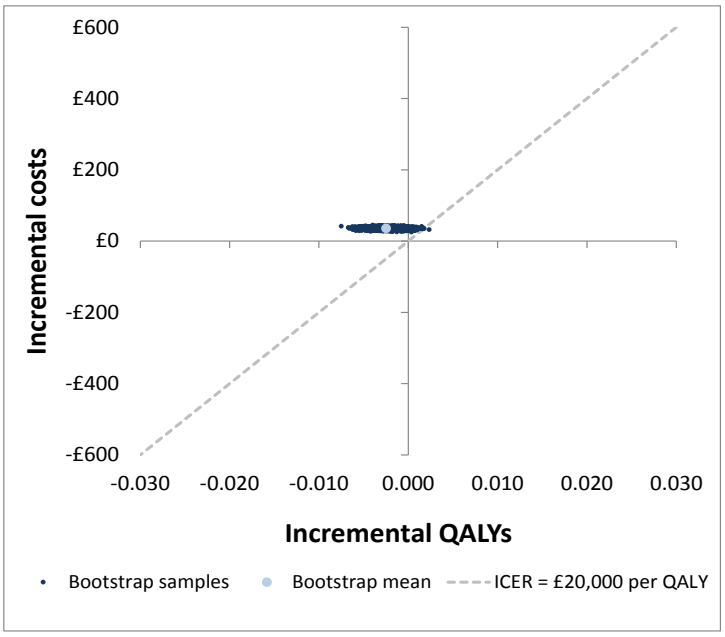

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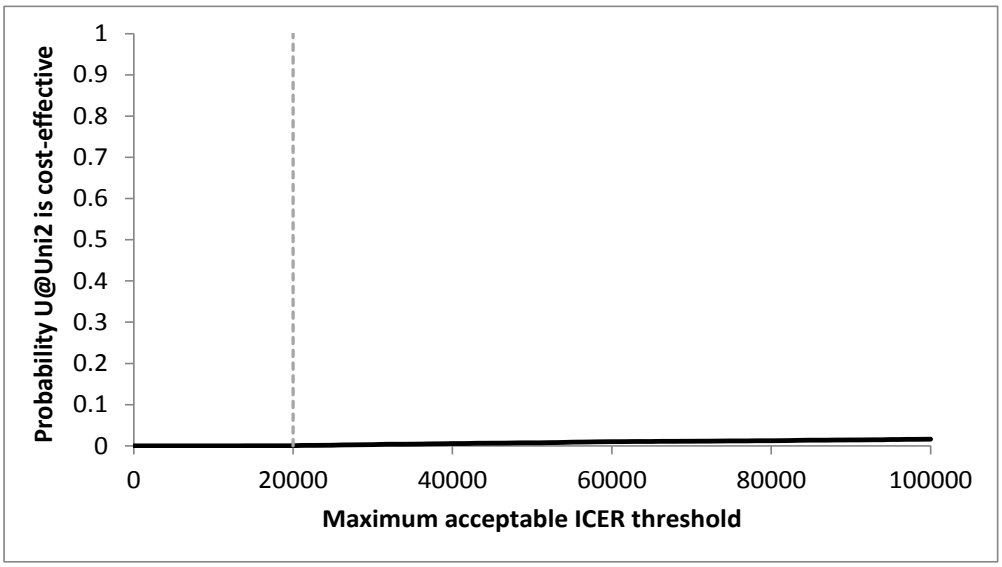

Figure 1. Within-trial cost-effectiveness planes and cost-effectiveness acceptability curves for U@Uni2 as compared to do nothing control. The individual-level cost-effectiveness plane and cost-effectiveness acceptability curve resulting from 5,000 bootstrap replicates in the within-trial cost-effectiveness analysis. **A)** Cost-effectiveness plane showing the incremental costs and QALYs accumulated over the 6 month trial period for full development and implementation of U@Uni2 compared to control. **B)** Cost-effectiveness acceptability curve showing the probability (out of 5,000 bootstrap replicates) that full development and implementation of U@Uni2 is cost-effective compared to control for a range of willingness-to-pay thresholds.

net benefit gained by U@Uni1 (£144) is slightly higher than for U@Uni2 (£104), due to its larger incremental QALY gain. However, there is a high level of uncertainty around the relative cost-effectiveness of the two interventions and they occupy similar distributions on the cost-effectiveness plane (Figure 2B).

Rolling out either intervention over a five year period is estimated to be cost saving as compared to control, as

Table 1. The incremental long-term cost-effectiveness of U@Uni (per person).

	U@Uni1 vs Control	U@Uni2 vs Control	U@Uni1 vs U@Uni2
Scenario 1: Full development and implementation of U@Uni1/U@Uni2			
Discounted life years	0.00070	0.00062	0.00008
Discounted QALYs	0.00767	0.00533	0.00233
Discounted costs	£152.94	£37.90	£115.04
ICER	£19.947	£7.106	£49.278
INB** at threshold of £20,000 per QALY	£0.41	£69	-£68
Probability cost-effective at willingness-to-pay threshold of £20,000 per QALY	48.7%	76.1%	24.1%
Scenario 2: Roll-out of U@Uni1/U@Uni2			
Discounted life years	0.00070	0.00062	0.00008
Discounted QALYs	0.00767	0.00533	0.00233
Discounted costs	£9.26	£2.86	£6.40
ICER	£1,207	£536	£2,741
INB** at threshold of £20,000 per QALY	£145	£104	£40
Probability cost-effective at willingness-to-pay threshold of £20,000 per QALY	92.7%	86.4%	65.9%
Scenario 3: Roll-out of U@Uni2 over five years			
Discounted life years	0.00070	0.00062	0.00008
Discounted QALYs	0.00767	0.00533	0.00233
Discounted costs	-£5.30	-£4.50	-£0.80
ICER	-£692	-£844	-£344
INB** at threshold of £20,000 per QALY	£159	£111	£47
Probability cost-effective at willingness-to-pay threshold of £20,000 per QALY	95.1%	88.2%	68.4%
Probability cost-saving at willingness-to-pay threshold of £20,000 per QALY	67.7%	66.7%	53.5%

*Any apparent discrepancies are due to rounding; **Incremental net monetary benefit = incremental QALYs x willingness-to-pay threshold – incremental costs.

the reduction in healthcare cost outweighs the cost of the interventions. £5.30 is saved per person for U@Uni1 and £4.50 is saved per person for U@Uni2. Again, both interventions are highly likely to be cost-effective when compared with control (INB of U@Uni1 = £159, probability cost-effective = 95%; INB of U@Uni2 = £111, probability cost-effective = 88%), and are cost-effective as compared to the standard roll-out from a cost-minimization perspective.

Structural sensitivity analyses

Sensitivity analyses suggest that the results are not sensitive to the removal of model updates, but they are sensitive to the method of imputation for missing data (Appendix Table 2).

The cost-effectiveness of all scenarios is correlated with the duration of intervention effect (Table 2). For roll-out, both interventions have almost 70% probability of being cost-effective even if the mean duration of intervention effect is only 1 year, and by 10 years, both interventions are cost saving. Rollout of both interventions over 5 years is highly likely to be cost-effective in all situations, but only becomes cost-saving if duration of intervention effect lasts for about 2-3 years.

The model allows assessment of the individual contribution of each health behaviour change to quality of life and mortality. Results show that the reduction in smoking accounts for almost 75% of the incremental life years gained with U@Uni1 and over 60% of the incremental life years gained with U@Uni2. An increase in physical activity accounts for a further 20% of incremental life years gained whilst the other two behaviours contribute only very slightly to mortality reductions. The utility effects of smoking are even more dramatic than the mortality effects, such that the entire QALY gain seen in both interventions is purely due to the effect of the interventions on smoking.

Value of information

Value of information analysis was performed for roll-out of the U@Uni2 intervention versus the control only. The overall value of information from EVPI analysis was found to be £6.54 per person for the roll-out of U@Uni2. The population potentially affected by the decision was the

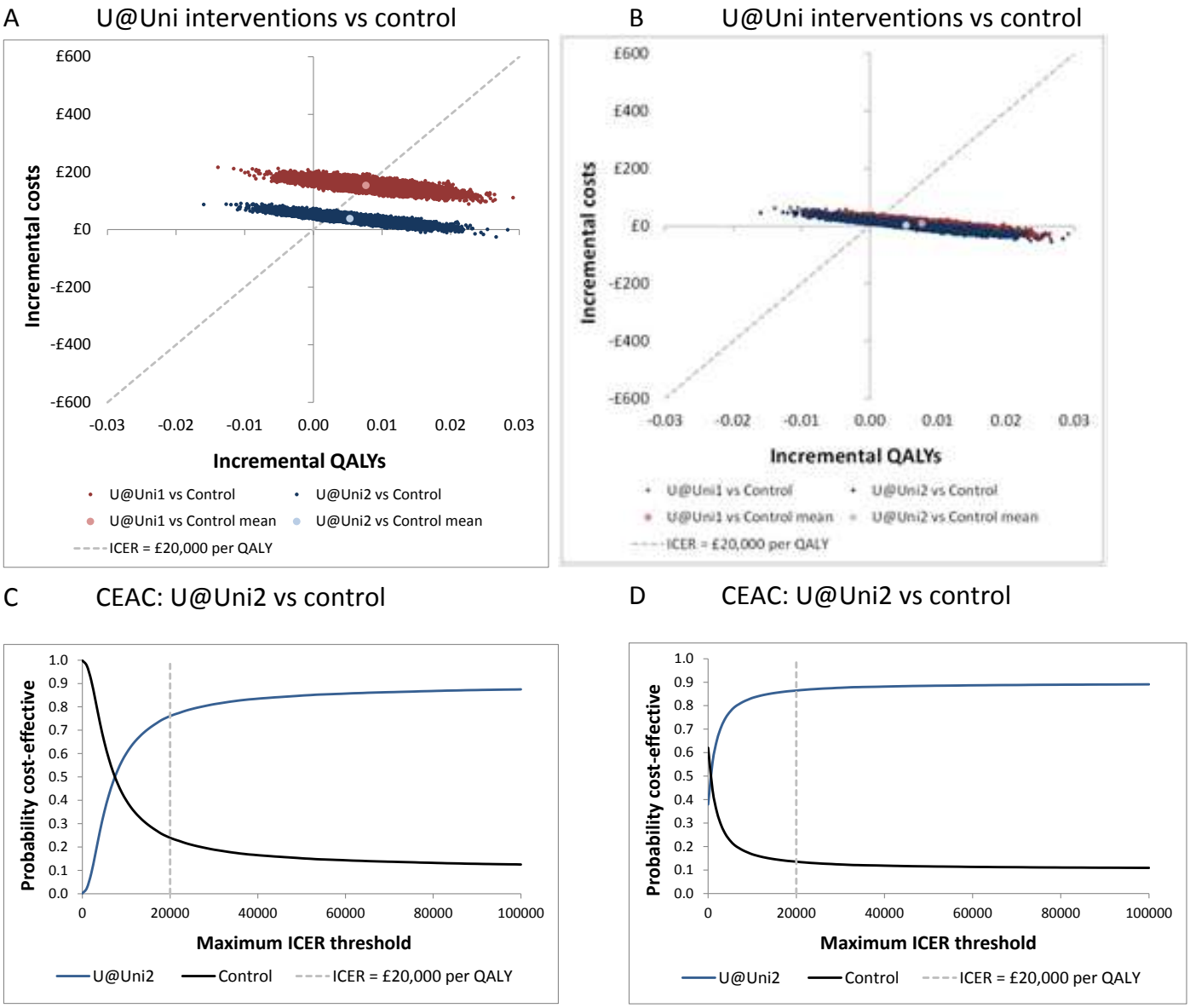

Figure 2. Cost-effectiveness planes and cost-effectiveness acceptability curves for long-term modelling of full implementation and roll-out of U@Uni1 and U@Uni2 interventions, compared to a do nothing control. **A)** Cost-effectiveness plane showing the per-person incremental discounted lifetime costs and incremental discounted lifetime QALYs for full implementation of U@Uni1 and U@Uni2 compared to a do nothing control. **B)** Cost-effectiveness plane showing the per-person incremental discounted lifetime costs and incremental discounted lifetime QALYs for roll-out of U@Uni1 and U@Uni2 compared to a do nothing control. **C)** Cost-effectiveness acceptability curve (CEAC) showing the probability (out of 30,000 PSA runs) that full development of U@Uni2 compared with control is cost-effective at different willingness-to-pay thresholds. **D)** Cost-effectiveness acceptability curve (CEAC) showing the probability (out of 30,000 PSA runs) that roll-out of U@Uni2 compared with control is cost-effective at different willingness-to-pay thresholds.

individuals starting university each year. In 2013, there were 495,560 UCAS acceptances in the UK (Universities and Colleges Admissions Service, 2013), meaning that it could be worth spending up to £3.24 million on further research that would enable an accurate decision to be made within a year. EVPPI analysis indicates that decision uncertainty is driven primarily by the parameters relating to the effects of the intervention on health behaviours, worth up to £3.79 per person or £1.9 million in total (Table 3). The individual parameters that have by far the most influence are the rates of non-smokers taking up smoking in the U@Uni2 and control conditions, which are worth 31p and 21p per person, respectively.

DISCUSSION

The U@Uni2 intervention is an updated version of the

Table 2. Comparison of incremental cost-effectiveness results over different durations of intervention effect.

DURATION OF EFFECT	U@Uni1 vs Control				U@Uni2 vs Control			
	QALYs	Costs	INB	Prob. CE	QALYs	Costs	INB	Prob. CE
Scenario 1: Full development and implementation of U@Uni1/U@Uni2								
1 yr	0.00185	£162.19	-£125.27	0.1%	0.00138	£43.76	-£16.22	34%
2 yrs	0.00367	£159.09	-£85.72	6.6%	0.00266	£41.69	£11.58	57.8%
5 yrs	0.00923	£150.16	£34.44	62.5%	0.00645	£36.29	£92.67	79.9%
10 yrs	0.01871	£135.72	£238.54	87.6%	0.01266	£28.68	£224.45	87.5%
Scenario 2: Roll-out of U@Uni1/U@Uni2								
1 yr	0.00185	£18.69	£18.23	68.7%	0.00138	£8.69	£18.85	69.6%
2 yrs	0.00367	£15.59	£57.78	83.7%	0.00266	£6.62	£46.65	80.5%
5 yrs	0.00923	£6.67	£177.94	94.4%	0.00645	£1.22	£127.74	87.7%
10 yrs	0.01871	-£7.78	£382.04	97.3%	0.01266	-£6.39	£259.52	90.7%
Scenario 3: Roll-out of U@Uni2 over 5 years								
1 yr	0.00185	£4.18	£32.74	80.9%	0.00138	£1.31	£26.23	76.0%
2 yrs	0.00367	£1.07	£72.29	91.0%	0.00266	-£0.75	£54.03	83.7%
5 yrs	0.00923	-£7.85	£192.45	96.2%	0.00645	-£6.15	£135.11	89.1%
10 yrs	0.01871	-£22.12	£396.38	97.8%	0.01266	-£13.76	£266.90	91.5%

QALY, Quality Adjusted Life Year; INB, Incremental Net Monetary Benefit; Prob. CE Probability Cost-Effective.

Table 3. EVPPI values for key single parameters and parameter combinations implicated in decision uncertainty when comparing U@Uni2 roll-out with a do nothing control.

Parameters	Roll-out of U@Uni2 vs Control		
	Per Person		UCAS population mean
	Mean	St. error	
Probability non-smokers start smoking (do nothing)	£0.21	£0.02	£105,100
Probability non-smokers start smoking (U@Uni2)	£0.31	£0.02	£153,800
Physical activity: U@Uni2 intervention coefficient	£0.00	£0.00	£2,392
All intervention effects total	£3.79	£0.15	£1,878,200
Intervention effects – all smoking parameters	£2.03	£0.15	£1,006,000
Intervention effects – all fruit/veg parameters	£0.00	£0.00	£0
Intervention effects – all physical activity parameters	£0.01	£0.01	£4,956
Intervention effects – all alcohol parameters	£0.00	£0.00	£0
Utility coefficients (all)	£0.44	£0.28	£218,000

U@Uni theory-based online health behaviour intervention for students as they start university (Cameron et al., 2015; Epton et al., 2014). This analysis shows that the U@Uni2 intervention is considerably cheaper to implement than U@Uni1. However, lifetime modelling indicates that U@Uni2 is likely to be less effective than U@Uni1, producing both fewer life years and fewer QALYs. Roll-out of U@Uni2 is highly likely to be more cost-effective than doing nothing, but is not likely to be more cost-effective than roll-out of U@Uni1.

The LifeGuide software was more user-friendly than the U@Uni1 website, and this together with some changes to trial design resulted in increased levels of recruitment and engagement with the intervention (Cameron et al., 2015). Despite these changes, the U@Uni2 intervention did not show a significant improvement in any of the four behaviours and the U@Uni2 trial itself was not found to be cost-effective due to a small reduction in health-related quality-of-life. QALY loss during the trial is likely to be due to stochastic sample variability and low sensitivity of the EQ-5D to measuring subtle changes in quality of life at the top of the scale (Brazier et al., 2007).

Improvements in smoking behaviour appear to account for the vast majority of life-years and QALYs gained for

both interventions. This is driven by the large effects smoking has on both quality of life and mortality compared with the other behaviours (Kruger et al., 2014; Kvaavik et al., 2010). A recent review of the economic impacts of smoking suggests that the direct costs of smoking may use 5% of the annual NHS budget, and far outweigh any economic benefits such as increased tax intake (Ekpu and Brown 2015). This suggests that specifically targeting smoking may not only be the best way to improve the health of young people, but will have positive economic consequences in the long term. In line with this, smoking cessation programmes aimed at young people have been found to be highly cost-effective in other economic analyses (Dino et al., 2008; Hollingworth et al., 2012).

A series of sensitivity analyses were carried out to test assumptions of model structure and methodology. Sensitivity analyses around the duration of intervention effect produced the largest changes in cost-effectiveness. Very little work has been done to investigate the likely duration of effect of online health interventions; this would be a useful area for further research. EVPPI analysis indicates that the highest level of decision uncertainty is around the effect of the intervention on health behaviours, particularly smoking. As intervention effectiveness is key to deciding whether to fund U@Uni2, decision makers may wish to invest in gathering more information to inform these parameters.

Taken together, the results of the two U@Uni trials suggest that online interventions can have a positive effect on health behaviours in new university students. These effects may be very small, but over a lifetime can result in significant health gains that are extremely cost-effective to implement. Similar small but positive effects have been found recently in other trials of online interventions aiming to reduce unhealthy behaviours in students (Kattelmann et al., 2014; Kypri et al., 2014). However, the U@Uni interventions remain unique amongst similar online health behaviour interventions in their demonstration of cost-effectiveness in addition to efficacy.

This study was performed from the perspective of the UK Department of Health; however, it is unclear whether they would be willing to fund such an intervention. Public health funding is concerned both with maximizing efficiency and reducing inequity (National Institute for Health and Clinical Excellence, 2012). University students are disproportionately from more privileged backgrounds (Universities and Colleges Admissions Service, 2014), and individuals with a degree have better health outcomes (Higher Education Funding Council for England, 2001) meaning that funding the U@Uni2 intervention could act to increase health inequalities. However, given the commitment of universities in England to the “Healthy Universities Scheme” to improve student health and well-being (UK National Healthy Universities Network, 2015), and the relatively low costs involved, larger universities may themselves wish to consider funding a U@Uni2 type intervention as part of their student health and well-being programme.

Conclusions and recommendations

This study estimates the costs and cost-effectiveness of U@Uni2, an updated version of the U@Uni trial of an online intervention targeting multiple health behaviours in new university students. The study shows that U@Uni type interventions are cost-effective to roll-out and suggests that universities committed to student health consider such an intervention given the low costs involved. Most of the decision uncertainty is associated with the effect of the intervention on health behaviour change, suggesting that further research should focus on this area. Given that intervention efficacy is almost entirely dependent on the smoking effect, targeting smoking is a priority for improving healthy behaviours in young people.

Conflict of interests

The authors have not declared any conflict of interests.

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Appendix

A full list of all the parameters used in the model and their values and distributions.

Table 1. Model input parameters.

Parameter	Distribution	Parameters*	Source
Individual baseline characteristics			
Age (years)	Individual-level data	Mean = 18.81 SD = 2.36	U@Uni2 RCT
Gender	Individual-level data	44.8% Male 55.2% Female	
Fruit and vegetables (portions per day)	Individual-level data	Mean = 4.49 SD = 2.27	
Alcohol (units per week)	Individual-level data	Mean = 6.87 SD = 9.51	
Physical activity (minutes per week)	Individual-level data	Mean = 814.16 SD = 765.95	
Smoking status	Individual-level data	2.9% Smoker 97.1% Non-smoker	
Costs			
U@Uni1 cost (full development)	Lognormal	Mean ln(cost) = 12.30663 SD ln(cost) = 0.05185	Costing analysis
U@Uni1 cost (roll-out)	Lognormal	Mean ln(cost) = 10.36116 SD ln(cost) = 0.06628	Costing analysis
U@Uni2 cost (full development)	Lognormal	Mean ln(cost) = 11.01548 SD ln(cost) = 0.09433	Costing analysis
U@Uni2 cost (roll-out)	Lognormal	Mean ln(cost) = 9.65251 SD ln(cost) = 0.07043	Costing analysis
U@Uni2 cost (roll-out over 5 years)	Lognormal	Mean ln(cost) = 8.41381 SD ln(cost) = 0.08173	Costing analysis
Intervention effect regression coefficients			
β_0 Fruit and vegetables: constant	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 0.7696	U@Uni1 & U@Uni2 RCTs
β_1 Fruit and vegetables: baseline behaviour coefficient		Mean = 0.4583	
β_2 Fruit and vegetables: age coefficient		Mean = 0.0722	
β_3 Fruit and vegetables: gender coefficient (1 = male; 0 = female)		Mean = -0.4053	
β_4 Fruit and vegetables: U@Uni1 intervention coefficient (i.e. mean effect of U@Uni1 on portions of fruit and vegetables per day compared to control)		Mean = -0.05387	
B_5 Fruit and vegetables: U@Uni2 intervention coefficient (i.e. mean effect of U@Uni2 on portions of fruit and vegetables per day compared to control)		Mean = 0.1714	
β_0 Alcohol: constant	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 14.720	U@Uni1 & U@Uni2 RCTs
β_1 Alcohol: baseline behaviour coefficient		Mean = 0.6408	
β_2 Alcohol: age coefficient		Mean = -0.5077	
β_3 Alcohol: gender coefficient (1 = male; 0 = female)		Mean = 2.8588	

Table 1. Contd.

β_4 Alcohol: U@Uni1 intervention coefficient (i.e. mean effect of U@Uni1 on units of alcohol per week compared to control)		Mean = -0.20932	
B_5 Alcohol: U@Uni2 intervention coefficient (i.e. mean effect of U@Uni2 on units of alcohol per week compared to control)		Mean = -0.5032	
β_0 Physical activity: constant	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 563.26	U@Uni1 & U@Uni2 RCTs
β_1Physical activity: baseline behaviour coefficient		Mean = 0.2068	
β_2 Physical activity: age coefficient		Mean = 2.1423	
β_3 Physical activity: gender coefficient (1 = male)		Mean = 77.835	
β_4 Physical activity: U@Uni1 intervention coefficient (i.e. mean effect of U@Uni1 on minutes of physical activity per week compared to control)		Mean = 25.93877	
B_5 Physical activity: U@Uni2 intervention coefficient (i.e. mean effect of U@Uni2 on minutes of physical activity per week compared to control)		Mean = 17.759	
Probability smokers quit smoking (U@Uni1)	Beta	α = 5.4 β = 13.6	U@Uni1 RCT
Probability non-smokers start smoking (U@Uni1)		α = 22.83 β = 547.17	
Probability smokers quit smoking (U@Uni2)	Beta	α = 3.72 β = 15.28	U@Uni2 RCT
Probability non-smokers start smoking (U@Uni2)		α = 27.47 β = 542.53	
Probability smokers quit smoking (do nothing)	Beta	α = 3.81 β = 17.19	
Probability non-smokers start smoking (do nothing)		α = 50.29 β = 602.71	
Lag effects (years until full effect of behaviour change on mortality risk)			
Fruit and vegetables lag	Lognormal	Mean = 2.7438 SD = 0.1247	Expert elicitation
Alcohol lag	Gamma	α = 1.3541 β = 0.6537	
Physical activity lag	Normal	Mean = 5.5000 SD = 1.4642	
Smoking lag	Normal	Mean = 5.5000 SD = 1.1110	
Distribution of individual-level duration of U@Uni behavioural effect (years)**			
Mean duration	Beta	α = 1.8179 β = 0.1304 Scale = 4.5000	Expert elicitation
Standard deviation of duration		α = 2.9109 β = 0.2691 Scale = 3.3800	
Hazard ratios for effect of health behaviours on mortality risk			
Fruit and vegetable consumption	Lognormal	Mean = 0.0953 SD = 0.0673	Kvaavik et al. (2010) (16)
Alcohol consumption		Mean = 0.1655 SD = 0.0840	

Table 1. Contd.

Physical activity		Mean = 0.3577 SD = 0.0641	
Smoking status		Mean = 0.3577 SD = 0.0873	
Utility ordinary least squares regression model coefficients			
β_0 Constant	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 0.9490	Analysis of Health Survey for England 2008 (17)
β_1 Age coefficient		Mean = -0.0038	
β_2 Gender (1 = male; 0 = female) coefficient		Mean = 0.0142	
β_3 Fruit and vegetables (portions per day) coefficient		Mean = 0.0207	
β_4 Alcohol (units per week) coefficient		Mean = 0.0016	
β_5 Smoke (smoker = 1; non-smoker = 2) coefficient		Mean = -0.0541	
β_6 Physical activity (minutes per week) coefficient		Mean = 0.0002	
β_7 Age^2		Mean = -4.31×10^{-06}	
β_8 Fruit and vegetables^2		Mean = -0.0033	
β_9 Fruit and vegetables^3		Mean = 0.0001	
β_{10} Alcohol^2		Mean = -2.77×10^{-05}	
β_{11} Alcohol^3		Mean = 6.45×10^{-08}	
β_{12} Physical activity^2		Mean = -2.59×10^{-07}	
β_{13} Physical activity^3		Mean = 4.88×10^{-11}	
β_{14} Age*Fruit and vegetables interaction		Mean = 4.94×10^{-05}	
β_{15} Age*Alcohol interaction		Mean = 1.61×10^{-05}	
β_{16} Age*Physical activity		Mean = 2.47×10^{-06}	
Age and sex dependent smoking quit rates			
Men aged 16-19	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 0.0469	Kemm et al. (2003) (11)
Men aged 20-24		Mean = 0.0219	
Men aged 25-34		Mean = 0.0193	
Men aged 35-44		Mean = 0.0186	
Men aged 45-54		Mean = 0.0354	
Men aged 55-64		Mean = 0.044	
Men aged 65-74		Mean = 0.0618	
Men aged 75+		Mean = 0.0484	
Women aged 16-19		Mean = 0.0551	
Women aged 20-24		Mean = 0.0178	
Women aged 25-34		Mean = 0.0288	
Women aged 35-44		Mean = 0.0255	
Women aged 45-54		Mean = 0.0239	
Women aged 55-64		Mean = 0.0563	
Women aged 65-74		Mean = 0.0581	
Women aged 75+		Mean = 0.0966	
Healthcare utilisation probit model regression coefficients			
β_0 Constant	Multivariate normal (see Additional file 1 for covariance matrix)	Mean = 2.519442	Analysis of Yorkshire Health Study (12)
β_1 Age coefficient		Mean = -0.03155	
β_2 EQ-5D coefficient		Mean = -0.81372	
β_3 Age^2		Mean = 0.000221	
β_4 EQ-5D^2		Mean = -1.27013	
β_5 Oldage (>=65 = 1; <65 = 0)		Mean = 0.174598	
β_6 Age*EQ-5D interaction		Mean = 0.01363	

Table 1. Contd.

β_7 Uni education (uni = 1, no uni = 0) coefficient		Mean = 0.089921	
β_8 Gender (1 = male; 0 = female) coefficient		Mean = -0.17944	
β_9 Smoke (smoker = 1; non-smoker = 2) coefficient		Mean = -0.09011	
Healthcare utilisation generalised linear model regression coefficients			
β_0 Constant	Multivariate normal	Mean = -1.78686	Analysis of Yorkshire Health Study (12)
B_1 EQ-5D coefficient		Mean = 7.478248	

*SD = standard deviation. **The sampled mean and standard deviation from the beta distributions are then converted to log (mean) and log (standard deviation) and used as parameters for the lognormal distribution for individual-level durations of response.

Table 2. Comparison of incremental cost-effectiveness results using different imputation methods.

IMPUTATION METHOD	U@Uni1 vs Control				U@Uni2 vs Control			
	QALYs	Costs	INB	Prob. CE	QALYs	Costs	INB	Prob. CE
Scenario 1: Full development and implementation of U@Uni1/U@Uni2								
MICE (default)	0.00767	£152.94	£0.41	48.7%	0.00533	£37.90	£68.76	76.1%
LOCF	0.00334	£165.11	-£98.41	17.9%	0.00418	£36.52	£47.07	68.1%
Complete Case	0.00625	£154.93	-£29.91	37.5%	0.00523	£37.37	£67.19	73.3%
Scenario 2: Roll-out of U@Uni1/U@Uni2								
MICE (default)	0.00767	£9.26	£144.09	92.7%	0.00533	£2.86	£103.80	86.4%
LOCF	0.00334	£21.40	£45.31	67.1%	0.00418	£1.54	£82.06	81.0%
Complete Case	0.00625	£11.37	£113.66	86.7%	0.00523	£2.31	£102.25	84.4%
Scenario 3: Roll-out of U@Uni2 over 5 years								
MICE (default)	0.00767	-£5.30	£158.65	95.1%	0.00533	-£4.50	£111.16	88.2%
LOCF	0.00334	£6.79	£59.91	72.2%	0.00418	-£5.84	£89.43	83.7%
Complete Case	0.00625	-£3.23	£128.26	89.7%	0.00523	-£5.06	£109.63	86.4%

MICE Multiple Imputation using Chained Equations; LOCF Last Observation Carried Forward; QALY Quality Adjusted Life Year; INB Incremental Net Monetary Benefit; Prob. CE Probability Cost-Effective.