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Efficacy of a web- and text messaging-based intervention to reduce problem drinking in adolescents: Results of a cluster-randomised controlled trial

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Abstract

Objective: To test the efficacy of a combined web- and text messaging-based intervention to reduce problem drinking in young people compared to assessment only. *Method:* Two-arm, parallel-group, cluster-randomised controlled trial with assessments at baseline and 6-month follow up. The automated intervention included online feedback, based on the social norms approach, and individually tailored text messages addressing social norms, outcome expectations, self-efficacy, and planning processes, provided over 3 months. The main outcome criterion was the prevalence of risky single-occasion drinking (RSOD, defined as drinking at least 5 standard drinks on a single occasion in men and 4 in women) in the past 30 days. Irrespective of alcohol consumption, 1,355 students from 80 Swiss vocational and upper secondary schools, all of whom owned a mobile phone, were invited to participate in the study. Of these, 1,041 (76.8%) students participated in the study. *Results:* Based on intention-to-treat analyses, RSOD prevalence decreased by 5.9% in the intervention group and increased by 2.6% in the control group, relative to that of baseline assessment (OR = 0.62, 95% CI = 0.44-0.87). No significant group differences were observed for the following secondary outcomes: RSOD frequency, quantity of alcohol consumed, peak blood alcohol concentration, and overestimation of peer drinking norms. *Conclusions:* The intervention programme reduced RSOD, which is a major indicator of problem drinking in young people, effectively. *Public health significance:* The participation rate for the automated intervention approach was high, and the intervention could be implemented for large groups of students easily within a school setting.

Keywords: alcohol, problem drinking, mobile phone, text messaging, adolescents

Background

Alcohol use is a major cause of disease burden in most countries worldwide (Lim et al., 2012). In the US, alcohol use disorders were associated with 15% and 24% of all deaths in young women and men aged 18–24 years, respectively (Rehm et al., 2014). Problem drinking in young people is associated with multiple social and interpersonal problems such as arguing with friends and parents, engaging in unplanned sexual activity, drinking and driving, assault, getting into trouble with the law, academic difficulties, unintended injuries, and suicidal acts; in the long term, problem drinkers exhibit an elevated risk of developing chronic conditions such as heart and liver disease or alcohol use disorders (Hingson, Edwards, Heeren, & Rosenbloom, 2009; Hingson, Heeren, & Edwards, 2008; Kuntsche & Gmel, 2013).

Indicators of problem drinking are (a) average daily consumption of more than 2 standard drinks in men and 1 standard drink in women (National Institutes of Health, 2015) and (b) risky single-occasion drinking (RSOD, also known as binge drinking), defined as drinking at least 5 standard drinks on a single occasion in men and 4 drinks on a single occasion in women (Gmel, Kuntsche, & Rehm, 2011). RSOD prevalence rates are particularly high in adolescence and young adulthood (Kuntsche, Rehm, & Gmel, 2004). In Switzerland, monthly RSOD prevalence is 32% in adolescents aged 15–19 years and 42% in young adults aged 20–24 years (Gmel, Kuendig, Notari, & Gmel, 2015). Relative to that of RSOD, the prevalence of elevated mean daily consumption in young people is low (3% at 15–19 years of age and 4% at 20–24 years of age), and it almost always occurs in combination with RSOD (Gmel et al., 2015).

To date, most studies examining the efficacy of interventions designed to reduce problem drinking in young people targeted college or university students and included personalized normative feedback based on the social norms approach (Perkins, 2003). The latter is based on the assumption that students typically overestimate the extent by which other students approve the use of alcohol (injunctive norm) and the quantity of alcohol that other students

actually consume (descriptive norm). An overestimation of peer alcohol use has been shown in several samples of young people (Franca, Dautzenberg, & Reynaud, 2010; Haug, Ulbricht, Hanke, Meyer, & John, 2011; Perkins, 2007) and was identified as one of the strongest predictors of alcohol consumption in this particular age group (Brooks-Russell, Simons-Morton, Haynie, Farhat, & Wang, 2014; Haug et al., 2011; Kypri & Langley, 2003; Neighbors, Lee, Lewis, Fossos, & Larimer, 2007). Presenting accurate information about peer group drinking norms is hypothesized to reduce the above-mentioned overestimation as well as the perceived peer pressure to consume high levels of alcohol (Perkins, 2002). Perceived peer drinking norm was also a relevant mediator of behavioural outcomes in multi-component programs addressing alcohol consumption among students (Paschall, Ringwalt, Wyatt, & Dejong, 2014; Walters, Vader, Harris, Field, & Jouriles, 2009). A systematic review on the efficacy of web- and computer-based personalized normative feedback in reducing problem drinking in young people reported significant effects on some of the regarded outcomes, however, the authors concluded that the effect sizes were too small to be of relevance for policy or practice (Foxcroft, Moreira, Almeida Santimano, & Smith, 2015). Herby, it must be considered that personalized normative feedback was often embedded in multi-component programs that also incorporated other elements such as information on local outpatient alcohol counselling services and elements derived from other theoretical approaches like outcome expectancies or protective behavioural strategies (Paschall, Antin, Ringwalt, & Saltz, 2011; Walters et al., 2009).

A recent review, which involved primarily student samples from the US and focused on computer- and web-based screening and brief interventions designed to reduce hazardous alcohol consumption, suggested that these interventions were effective in reducing alcohol consumption with follow-up periods of less than 12 months, but this was not observed with longer-term follow-up periods (Donoghue, Patton, Phillips, Deluca, & Drummond, 2014).

Based on the available reviews and recently published RCTs on alcohol screenings and brief

interventions for adolescents (Patton et al., 2014), electronic brief interventions could be considered to induce behavioural changes cost-effectively, and young people found them more acceptable relative to face-to-face approaches.

To date, computer and web-based brief interventions to reduce problem drinking typically consist of a single or a few intervention sessions in which participants receive tailored web-based or printed feedback, which typically consists of 7–8 pages of text and graphics (Donoghue et al., 2014; Foxcroft et al., 2015). While pictographic information provided via computer or the Internet have been shown to be appropriate to present personalized normative feedback, an additional provision of shorter and more frequent feedback messages might be a more effective approach to support and maintain behaviour change over a longer period. Text messaging is a suitable means of delivering short, repeated messages. This service allows cost-effective, instantaneous, direct delivery of messages to individuals at any time and location. Text messaging is beneficial in the field of alcohol prevention, because it allows delivery of individualized messages at times when young people typically drink alcohol, i.e. on weekends and late at night (Kuntsche & Robert, 2009). In Switzerland, as in most developed countries, almost all (98%) adolescents between the ages of 12 and 19 own a mobile phone, and 97% of these phones are smartphones (Willemse et al., 2014).

Concerning alcohol use in young people, the efficacy of interventions involving text messaging has been assessed in 3 pilot studies with relatively small sample sizes (Mason, Benotsch, Way, Kim, & Snipes, 2014; Moore et al., 2013; Suffoletto, Callaway, Kristan, Kraemer, & Clark, 2012) and 2 larger-scale studies (Haug et al., 2013; Suffoletto et al., 2014). Suffoletto et al. (2014) evaluated the efficacy of an assessment and feedback intervention involving text messaging, provided after emergency department discharge, in young adults exhibiting hazardous alcohol consumption. At 9-month follow up, participants in the intervention group reported greater reductions in the number of RSOD days, lower RSOD

prevalence, fewer drinks per drinking day, and lower alcohol-related injury incidence relative to participants in the control group, who received standard care (Suffoletto et al., 2015).

Haug et al. (2013) assessed the acceptance and initial efficacy of a combined, individually tailored web- and text messaging-based intervention designed to reduce problem drinking in Swiss vocational school students in a pre-post study. The results showed a significant reduction from 76% at baseline to 68% at 3-month follow up in the proportions of individuals reporting RSOD.

In the present study, we evaluated the efficacy of an optimized version of this programme within an adequately powered, cluster-randomized controlled trial. While previous studies either addressed interventions providing computer/web-based feedback or text messages, this study tested the efficacy of an intervention program combining the advantages of two communication channels – a comprehensive pictographic web-based feedback and concise text messages provided over a period of three months, some of which were sent on individually indicated typical drinking times.

The intervention addressed young people irrespective of the presence or level of problem drinking. With respect to data protection regulations, feasibility, and the avoidance of discrimination against certain students, the provision of an individualized primary prevention intervention has several advantages over secondary prevention interventions focusing on problem drinkers. However, few studies have assessed the efficacy or potential iatrogenic effects (Werch & Owen, 2002) of web-based alcohol interventions for non-problem drinkers (Bertholet et al., 2015a; Palfai, Winter, Lu, Rosenbloom, & Saitz, 2014). In order to address this, ancillary subgroup analyses included groups that differed with respect to the presence and level of problem drinking.

Method

Study Objectives and Design

The study aimed to determine the efficacy of a combined web- and text messaging-based intervention designed to reduce problem drinking in young people. The study was registered at Current Controlled Trials ISRCTN (59944705, assigned 10 July 2014). The two-arm, parallel-group, cluster-randomised controlled trial used school class as a randomisation unit and compared the efficacy of the intervention to that of assessment only. The trial was conducted in Switzerland, and participants were recruited between September 2014 and March 2015. The 6-month follow-up assessments were conducted between March and September 2015, and the study protocol was published on 7 August 2014 (Haug, Kowatsch, Castro, Filler, & Schaub, 2014). Students in vocational and upper secondary schools were invited to participate, irrespective of level of alcohol use. The intervention was based on the social norms approach (Perkins, 2003) but also included elements of major psychological models of health behaviour change such as social cognitive theory (McAlister, Perry, & Parcel, 2008) and the health action process approach (Schwarzer, 2008). Text messages were sent to participants over 3 months and tailored according to data gathered at baseline and during repeated text message assessments. At 6-month follow up, we expected to observe lower RSOD prevalence for the preceding 30 days in students in the intervention group, relative to that observed in the control group. Secondary outcome measures included frequency of RSOD occasions in the preceding 30 days, quantity of alcohol consumed during a typical week in the preceding 30 days, peak blood alcohol concentration, and overestimation of peer drinking norms. The study protocol was approved by the ethics committee of the philosophical faculty at the University of Zurich, Switzerland (date of approval: 24 June, 2014). The trial was executed in compliance with the Declaration of Helsinki.

The study was implemented as described in the study protocol (Haug et al., 2014), with the following modification: To consider the nested data structure for students in classes adequately (intra-class correlation for primary outcome was 9.1% and 8.4–11.6% for secondary outcomes), we performed generalized linear mixed modelling (GLMM; Laird &

Ware, 1982) rather than generalized estimation equation analyses (Zeger, Liang, & Albert, 1988).

Participants, Setting, and Procedure

The intervention assessment involved vocational and upper secondary school students because of their heterogeneous educational level and age range, which was primarily 16–19 years. Alcohol consumption is considerably higher in this age group relative to that observed at a younger age (Gmel et al., 2015), and Internet use and text messaging are widespread (Willemse et al., 2014). Prevention specialist centres in the Swiss cantons of Zurich and Berne invited vocational and upper secondary schools to participate in a study examining the efficacy of a web- and text messaging-based programme designed to reduce problem drinking. Eleven vocational and upper secondary schools, with 80 classes in total, agreed to participate in the study.

Research assistants (psychology master's degree students or graduates) invited all of the students in the participating classes to take part in an online health survey during a regular school lesson reserved for health education. To reduce reporting bias, research assistants did not provide further information regarding the purpose of the study before screening was complete. Online screening was performed between September 2014 and March 2015 using tablet computers. Demographic data, general health, alcohol consumption, weekly physical activity, smoking status, and mobile phone ownership were assessed. The only inclusion criterion for study participation was ownership of a mobile phone. Eligible individuals were informed about data protection, the aim of the study, assessments, and reimbursement.

Research assistants provided study and programme information online and on paper. Eligible individuals were informed that they could withdraw from participation at any time by sending a text message expressing this intention. To ensure sufficient participation, a reward of 10 Swiss francs was offered for participation in the study at both baseline- and follow-up

assessment. After providing informed consent online, all participants were invited to choose a username and provide a mobile phone number.

Subsequently, participants in the intervention group were provided with additional questions, which were necessary in tailoring intervention content, and received individualized feedback, which was based on the social norms approach, via their tablet computers (see Intervention section). During the subsequent 3 months, the intervention group received 1–3 individually tailored text messages per week to reduce problem drinking. The assessment-only group received no intervention.

Follow-up assessments were conducted using tablet computers, during regular lessons and under the supervision of research assistants, 6 months later. Computer-assisted telephone interviews were conducted when assessments could not take place during a school lesson because of vacations, class resolution, or study participants' absence from class ($n = 163$).

Randomisation and Allocation Concealment

To avoid spill-over effects within classes, we conducted a cluster-randomised controlled trial using school class as a randomisation unit. Because of the heterogeneity of apprentices in the different vocational and upper secondary school classes (e.g. concerning sex or profession), we used separate randomisation lists for each school (stratified randomisation). Furthermore, to approximate sample size equality in the study groups, we used block randomisation with computer-generated, randomly permuted blocks of 4 school classes (Pocock, 1994).

Research assistants supervising the baseline assessment in the vocational schools were blinded to the group allocation of school classes. In addition, group allocation was not revealed to participants until they had provided their informed consent, username, mobile phone number, and baseline data. Furthermore, the research assistants who performed the computer-assisted follow up assessments for primary and secondary outcomes were blinded to the group allocation.

Sample Size Calculation

An estimation of effect size was based on the results of the pre-post study in which the initial efficacy of the programme was assessed (Haug et al., 2013). This study revealed a reduction, from 76% at baseline to 68% at follow up, in the proportion of individuals who reported at least 1 RSOD occasion during the preceding month. Improvements in the content and tailoring of the intervention were expected to result in improved efficacy. Based on these considerations, the proportions of individuals reporting at least 1 RSOD occasion in the month preceding follow-up were estimated at 76% in the control group and 66% or lower in the intervention group. Each study groups required 322 participants to ensure 80% power in an χ^2 test ($\alpha = 5\%$, 2 sided) and detect differences based on a calculation using *G*Power* (Faul, Erdfelder, Lang, & Buchner, 2007). As students are nested within school classes, a potential design effect required consideration. Based on the pre-post study conducted (Haug et al., 2013), we expected an average cluster size of 10 participants per class and an intra-cluster correlation coefficient of 0.05. This resulted in a design effect of 1.45. Multiplying this design effect by the required size for a non-nested sample ($n = 322$) resulted in a requirement for 467 participants per study group and a total sample size of 934.

Intervention

Overview

The intervention programme, *MobileCoach Alcohol*, is a combined, individually tailored intervention with a web- and text messaging-based part. It combines a single web-based feedback provided immediately after a baseline assessment and individually tailored text messages provided over the intervention period of 3 months. The division into a web-based and a text messaging part was driven by time constraints (providing a comprehensive feedback within a school lesson, whereas short text messages were sent repeatedly during

leisure time), considered the cognitive capacity and motivation of students (higher for shorter intervention elements) and took into account that each technology has its own advantages.

Technological Background

The intervention programme, *MobileCoach Alcohol*, was developed using the *MobileCoach* system. Details of the system were described in (Haug et al., 2014). The source code for the *MobileCoach* system is available as an open-source project on <http://mobile-coach.eu>.

Password protection and Secure Sockets Layer encoding were used to ensure the privacy and safety of data transfer.

Theoretical Background

The web-based part of the intervention primarily provided normative feedback based on the social norms approach (Perkins, 2003). The text messaging-based part of the intervention primarily relied on the following socio-cognitive constructs from major psychological models of health behaviour change such as social cognitive theory (McAlister et al., 2008) and the health action process approach (Schwarzer, 2008): outcome expectations, self-efficacy, and planning processes.

Web-based Feedback

The web-based feedback was based on age- and gender-specific norms for alcohol consumption from a previous study (Gmel, Venzin, Marmet, Danko, & Labhart, 2012) that assessed heavy drinking occasions, alcohol volume, and the maximum number of drinks consumed on a single occasion in 973 vocational and upper secondary school students in the canton of Zurich, Switzerland. The web-based feedback included individually tailored graphical and textual information concerning (1) the number of drinks consumed per week in relation to the age and gender-specific reference group, (2) financial costs of drinking, (3)

calories consumed with alcoholic drinks, and (4) number of RSOD occasions in relation to the age- and gender-specific reference group.

Text Messages

On the first level, the content and number of text messages were tailored according to baseline drinking patterns. Participants were assigned to one of 3 risk groups derived from (Gmel et al., 2011; National Institutes of Health, 2015) according to their baseline drinking patterns: (1) low risk: No RSOD occasions during the preceding 30 days and ≤ 14 (7 for girls) standard drinks consumed during a typical week, (2) medium risk: 1 or 2 RSOD occasions during the preceding 30 days or no RSOD occasions during the preceding 30 days and ≥ 14 (7 for girls) standard drinks consumed during a typical week, and (3) high risk: > 2 RSOD occasions during the preceding 30 days.

On the second level, the content of the text messages was tailored according to individual values for the following baseline variables: sex, motivation to reduce alcohol consumption, alcohol-related problems, typical drinking day and time, peak blood alcohol concentration during the preceding 30 days, positive outcome expectancies, typical drinking situations, strategies to resist alcohol in different drinking situations, and assessment location (canton of Zurich vs. canton of Berne). Participants from all risk groups received text messages for 3 months.

Text messages for the low risk group focused on (a) motivation for drinking within low-risk limits using individual data concerning positive outcome expectancies derived from a list provided by (Babor & Higgins-Biddle, 2001) and (b) strategies to resist alcohol in different drinking situations, using individual data obtained using the adolescent version of the Drinking Refusal Self-Efficacy Questionnaire (Young, Hasking, Oei, & Loveday, 2007).

Within the medium risk group, the text messages focused on (a) motivation to drink within low risk limits, using individual data concerning positive outcome expectancies derived from

a list provided by (Babor & Higgins-Biddle, 2001); (b) alcohol-related problems, established using individual data on previous alcohol-related problems; (c) peak blood alcohol concentration and related risk calculated using data concerning sex, body weight, and maximum number of drinks consumed on a single occasion in the preceding month; and (d) strategies to resist alcohol in different drinking situations, established using data concerning individual drinking situations and chosen strategies for resisting alcohol. Text messages concerning the last-mentioned category were sent on individually indicated typical drinking days and times.

Similar to those in the medium risk group, participants in the high risk group received 2 text messages per week from the content categories described above (a–d). In addition, they received information regarding local outpatient alcohol counselling services according to assessment location. Sample text messages for the different risk groups and content categories are shown in Table 1.

Irrespective of risk group, 3 short message service (SMS) text message assessments were performed during the intervention period: (1) An SMS quiz on the metabolism of alcohol, for which participants received immediate individualized feedback on their answers, and if they did not respond within 48 hours, they were sent the correct response. (2) A message contest that required participants to create a text message to motivate other participants to drink within low-risk limits. The best text message, rated weekly by an alcohol prevention specialist from the Swiss Research Institute for Public Health and Addiction, was sent anonymously to all other participants after 48 hours. (3) An SMS assessment of RSOD within the preceding week, which included immediate individualized feedback.

The text messages typically contained 150–300 characters. Several text messages also included web links to thematically appropriate video clips, pictures, and websites. Sample text messages are displayed in Table 1.

Participants in the low risk group received 16 text messages (1 welcome message, 3 assessment messages, 11 tailored feedback messages, and 1 goodbye message). Participants in the medium- and high-risk groups received 27 text messages (1 welcome message, 3 assessment messages, 22 tailored feedback messages, and 1 goodbye message).

The total number of different text messages across all risk groups was 119 (low risk: 39, medium risk: 95, high risk: 97; due to overlapping/identical text messages they do not add up to 119). As many text messages contained individual values (e.g., peak blood alcohol concentration) or weekly changing top messages from the message contest, the variety of text messages was much larger.

Control Group

Participants in the assessment-only group did not receive any of the previously described interventional elements of the *MobileCoach Alcohol* programme.

Assessments and Outcomes

The online baseline screening assessment included the following demographic and health-related variables: sex, age, school education, immigration background, general health, physical activity, and tobacco smoking. The following common levels of educational attainment in Switzerland were assessed: (1) secondary school, (2) vocational school, and (3) technical/high school or university. In further analysis, we collapsed vocational school and technical/high school or university into a high educational level, and secondary school was coded as a low educational level. We assessed countries of birth in students' parents, to identify a potential immigrant background. Based on this information, participants were assigned to one of the following categories: (1) neither parent born outside Switzerland, (2) 1 parent born outside Switzerland, or (3) both parents born outside Switzerland. In the analysis, we collapsed 1- and

2-sided immigrant backgrounds into a single category and compared it to a non-immigrant background.

Self-rated general health (Idler & Benyamini, 1997) was assessed using the following item: ‘Would you say that your general health is: (1) excellent, (2) very good, (3) good, (4) fair, or (5) poor?’ Self-reported moderate to vigorous physical activity was measured using the following question derived from the Health Behaviour in School Aged Children study (Suppli et al., 2012): ‘Outside school, how many hours per week do you exercise or participate in sports that make you sweat or out of breath?’ Tobacco smoking was assessed using the following question: ‘Do you currently smoke cigarettes or have you smoked in the past?’ with the following response options: (1) I smoke cigarettes daily; (2) I smoke cigarettes occasionally but not daily; (3) I smoked cigarettes in the past, but I do not smoke anymore; and (4) I have never smoked cigarettes or have smoked less than 100 cigarettes throughout my life.

Baseline and follow up assessments included the following variables concerning alcohol use:

(a) RSOD prevalence in the preceding 30 days, assessed by asking participants to report the number of standard drinks consumed on the heaviest drinking occasion in the preceding 30 days. Examples of standard drinks containing 12–14 g of ethanol were provided for beer, wine, spirits, alcopops and cocktails, along with conversion values (e.g. three 0.5 l cans of beer = 6 standard drinks). RSOD was defined as drinking at least 5 drinks on a single occasion in men and 4 drinks on a single occasion in women (Gmel et al., 2011).

(b) Frequency of RSOD occasions in the preceding 30 days (‘How often did you have 5 (boys; girls: 4) or more drinks on a single occasion in the last 30 days?’).

(c) Quantity of alcohol consumed, assessed via a 7-day drinking calendar similar to the Daily Drinking Questionnaire (Collins, Parks, & Marlatt, 1985), for which participants were asked to think about a typical week in the preceding month and record the number of standard drinks they typically consumed each day during that week.

(d) Peak blood alcohol concentration, assessed by asking participants to report the number of standard drinks consumed and the duration of the heaviest drinking episode in the preceding 30 days. This information was used, along with the sex and weight, to estimate peak blood alcohol concentration based on the Widmark Formula (National Highway Traffic Safety Administration, 1994; Yang, Fung, & Tam, 2009).

(e) Overestimation of peer drinking norms using reference data from Gmel et al. (2012) and items derived from Haug et al. (2011), who used modified versions of the first and second consumption items of the Alcohol Use Disorders Identification Test (Bradley et al., 2007; Haug et al., 2011): ‘How often does a typical (male/female) adolescent at the age of (xx years) have a drink containing alcohol?’ and ‘How many drinks does a typical (male/female) adolescent at the age of (xx years) years have on a typical day when drinking alcohol?’ The prevalence of overestimation of peer drinking norms was calculated by multiplying the indicated alcohol consumption quantity and frequency for a typical (male/female) adolescent at the corresponding age and subtracting this amount from the reference data (Gmel et al., 2012). Values of the perceived norm that were above those of the reference/actual norm were interpreted as overestimation.

The primary outcome of the planned study was RSOD in the 30 days preceding follow-up assessment. Secondary outcomes included (a) frequency of RSOD occasions in the 30 days preceding follow-up assessment, (b) peak blood alcohol concentration in the preceding 30 days, (c) number of standard drinks consumed in a typical week during the preceding month, and (d) overestimation of peer drinking norms.

Indicators of program use and program attrition among participants of the intervention group were examined. Log files of the *MobileCoach* system in which all incoming and outgoing text messages were recorded were analyzed to obtain the number of participants who unsubscribed from the program (program attrition). At follow-up, the usage of text messages was assessed as well by asking participants whether they had received text messages regularly and if so (1)

read through the text messages thoroughly, (2) took a quick look at the text messages, or (3) did not read the text messages. Furthermore, it was assessed whether the number of received text messages was appropriate or whether the participants would have preferred fewer or more messages.

Data Analysis

We initially examined the data for outliers, based on self-reported numbers of standard drinks, which were entered as free text. Based on a visual inspection of the distributions and the recommendations of Osborne and Overbay (2004), outliers were identified at more than 3 standard deviations above the mean and adjusted to 3 standard deviations above the mean. To test for baseline differences between participants of the intervention and control group, chi-square tests were performed for categorical variables, and t tests and Mann-Whitney U tests were performed for continuous variables. To assess attrition bias we also used chi-square tests for categorical variables and Mann-Whitney U-tests and t tests for continuous variables to test whether participants lost to follow up differed from those who responded as a function of study group (intervention vs. control group).

Intervention effects for binary outcomes were tested using GLMM; intervention effects for continuous outcomes were analysed using linear mixed modelling. Analyses of binary outcomes focused on follow-up values. Independent variables included baseline values for the interesting binary variables, variables for which baseline or attrition differences were observed (fixed effects), and class as a single random effect (random intercept). Analyses of continuous outcomes included change in score from baseline to follow up as the dependent variable. Independent variables included baseline values, variables for which baseline or attrition differences were observed (fixed effects), and class as a single random effect (random intercept). This model controlled for the correlation between baseline and follow-up outcome scores and did not require a random effect for time or a time \times group interaction

term to interpret intervention effects (Twisk, 2013). Finally, GLMM and linear mixed modelling were used in ancillary analyses of the outcomes used in the main analyses, with the low-, medium-, and high-risk groups analysed separately. Intra-class correlation for primary and secondary outcomes ranged from 8.4% to 11.6% in the overall analyses and from 5.8% to 52% in the subgroup analyses. All analyses were based on a complete-case (CC) dataset and an intention-to-treat (ITT) dataset with imputation of continuous missing follow-up data based on expectation maximization, and with imputation of dichotomous missing follow-up data based on predictive mean matching (Hothorn & Everitt, 2014; Van Buuren, 2012). Distributions of outcomes (e.g. skew and kurtosis) and missing-at-random requirements for missing data were checked prior to performing the main analyses. Results with a Type I error rate of $p < 0.05$ in two-sided tests were considered statistically significant. Analyses were performed using SPSS version 22 and R version 3.2.1 via lme4 (Bates, Maechler, Bolker, & Walker, 2014) and mice (Buuren & Groothuis-Oudshoorn, 2011) packages.

Results

Study Participation

Figure 1 depicts participants' progression through the trial. At online screening assessment, 1,399 students were present in 80 classes. Of these, 1,371 (98.0%) agreed to participate and completed the health survey, 1,355 met the inclusion criterion of ownership of a mobile phone, and 1,041 (76.8%) ultimately participated in the study. Forty-three classes containing 547 students in total were randomly assigned to the intervention group, and 37 classes containing 494 students in total were assigned to the control group. Follow-up assessments were completed by 511 (93.4%) and 455 (92.1%) participants in the intervention and control groups, respectively.

Programme Attrition and Use

During the intervention programme, which lasted for 12 weeks, 5 of the 547 (0.9%) programme participants withdrew their participation. Of 509 participants with valid follow-up data, 479 (94.1%) indicated that they had received text messages regularly. Of these, 65.6% (315) indicated that they 'read the SMS messages thoroughly', 32.6% (156) reported that they 'took a quick look at the SMS messages', and 1.7% (8) chose the predefined response category 'I did not read the SMS messages'. The number of text messages received was rated as appropriate by 71.5% (337/471) of participants; 10.0% (47/471) would have preferred fewer messages, 8.7% (41/471) would have preferred more text messages, and 9.8% (46/471) were no longer able to evaluate the appropriateness of the number of text messages received.

Sample Characteristics

Baseline characteristics for the study sample are shown in Table 2. Baseline differences between the intervention and control groups were detected only for smoking status, with a significantly higher proportion of smokers in the intervention group ($\chi^2 = 10.4, p = .01$). Concerning attrition bias, the analysis revealed that intervention group participants who were lost to follow up were more likely to report a low educational level ($\chi^2 = 6.6, df = 2, p < .01$) and estimate the quantity of alcohol consumed by peers to be low ($\chi^2 = 17.3, df = 7, p = .02$) compared to control group participants who were lost to follow up.

Primary Outcome Analysis

The results of the ITT analysis examining RSOD prevalence are displayed in Table 3 and Figure 2. In the 30 days preceding follow-up assessment, RSOD prevalence decreased by 5.9% (from 47.2% to 41.3%) in the intervention group and increased by 2.6% (from 42.7% to 45.3%) in the control group, relative to that observed at baseline. This group effect was significant in the ITT analysis (OR = 0.62, $p < .01$) but not in the CC analysis (OR = 0.79, $p = .24$).

Secondary Outcome Analysis

Results concerning secondary outcomes are summarised in Tables 3 and 4. As the results of ITT analysis and CC analysis did not differ with respect to statistical significance, only those for the ITT analysis are reported. No significant group effect was observed for pre-post difference in RSOD frequency (-0.07 vs. 0.05, $p = .19$). Quantity of alcohol consumed in a typical week decreased by 0.94 standard drinks in the intervention group and 0.37 standard drinks in the control group ($p = .58$) from baseline to follow up assessment. Pre-post differences in peak blood alcohol concentration (-0.14 in the intervention group and -0.03 in the control group, $p = .16$) and overestimation of peer drinking norms (-1.1% in the intervention group and -0.8% in the control group, $p = 0.69$) did not differ significantly between groups.

Ancillary Subgroup Analysis

Results stratified according to risk group (low, medium, high) are summarized in Tables 5 and 6. The results of the ITT analysis examining RSOD prevalence by risk group are displayed in Figure 2. With regard to their statistical significance, the results of the ITT subgroup analyses did not differ from those of the CC analyses. Group effects were detected exclusively for participants for whom baseline assessment indicated that they were at high risk of problematic alcohol use, which was defined as > 2 RSOD occasions during the 30 days preceding baseline assessment.

Within this high-risk group, RSOD prevalence decreased by 23.7% (from 100% to 76.3%) in the intervention group and 8.1% (from 100% to 91.9%) in the control group (OR = 0.29, $p = .047$) relative to that observed at baseline. Frequency of RSOD in the preceding 30 days decreased by 1.48 in the intervention group and 0.86 in the control group (Cohen's $d = 0.34$, p

= .01), and peak blood alcohol concentration decreased by 0.58 in the intervention group and 0.14 in the control group (Cohen's $d = 0.38$, $p = .03$).

Discussion

This study aimed to determine the efficacy of a combined web- and text messaging-based intervention designed to reduce problem drinking in Swiss upper secondary and vocational school students. Four main findings were revealed: (1) the intervention approach reached the majority of students, with 3 out of 4 participating in the programme and associated study. (2) According to the ITT analysis, the intervention resulted in a significant reduction in RSOD prevalence relative to that observed in the control group. (3) Based on subgroup analysis, high-risk alcohol users characterized by at least 2 RSOD occasions within the preceding month benefited from the intervention. (4) Neither positive nor negative intervention effects were observed in the subgroup of students who were not at risk of alcohol use.

Similar to a previous pre-post study examining this intervention approach (Haug et al., 2013), 3 out of 4 students who were invited to participate in the programme and study agreed to do so. Given the 3-month duration of the programme and the requirement for provision of a mobile phone number, the participation rate was considered very high. The main reason for the high participation rate could have been a combination of the proactive nature of the invitations to participate received by school classes and the offer of an attractive, low-threshold mobile phone-based intervention. In a comparison of recent studies in which young people were recruited for web-based alcohol interventions irrespective of drinking level, a more reactive recruitment approach involving e-mail invitation revealed a participation rate of 37% in young Swiss men (Bertholet et al., 2015a); in addition, a study involving ninth-grade students from the US resulted in a participation rate of 52% (Doumas, Esp, Turrisi, Hausheer, & Cuffee, 2014). As reported in an accompanying paper on student accessibility to the *MobileCoach Alcohol* programme (Haug, Paz Castro, & Schaub, 2015), female sex, younger

age, and a higher maximum number of standard drinks per occasion were associated with higher participation rates. Beyond participation, retention was also very good, and nearly all participants remained logged in until the end of the programme, which could have occurred because most participants evaluated the number of text messages as appropriate.

The ITT results concerning the primary outcome, RSOD, showed significant intervention effects for the total sample and the subgroup characterized by initial high-risk alcohol consumption. Although the subgroup analyses were underpowered for detecting differences at the conventional alpha level, the results suggest that particularly heavy drinkers benefited from the intervention, with reductions of 23.7% and 8.1% in RSOD prevalence in the intervention and control groups, respectively. The more pronounced intervention effect observed in heavy drinkers is consistent with the results of another recently published Swiss study, in which a web-based intervention exerted an effect in young men who reported unhealthy alcohol use (Bertholet et al., 2015b), but this effect was not observed in those who did not report unhealthy alcohol use (Bertholet et al., 2015a). Contrary to our findings, (Bertholet et al., 2015a) reported significant intervention effects on number of drinks consumed per week, with no effect observed on RSOD prevalence. A possible explanation for this is that our text messages were designed to reduce RSOD, and some were sent on individually indicated typical drinking days and times.

With respect to the potential iatrogenic effects (Werch & Owen, 2002) of web-based alcohol interventions, the results of the subgroup analyses underlined those of recently published studies (Bertholet et al., 2015b; Prince, Reid, Carey, & Neighbors, 2014) in which normative feedback did not lead to a stronger increase in drinking in those who did not report problem drinking, compared to control group participants. Rather, a protective effect of the intervention might be assumed as 21.2% of the initial low risk control group participants but only 16.8% of the initial low risk intervention group participants showed RSOD at follow up. Considering that the subgroup analyses were underpowered and showed no significant effect

but a tendency towards a protective effect on the main outcome, further adequately powered studies should be conducted to determine efficacy in low and medium risk drinkers.

Furthermore, studies should be conducted to compare the efficacy of substance-related intervention concepts, such as normative feedback, and more general skills-based interventions, which are promising in this subgroup of low risk drinkers (Spath, Greenberg, & Turrisi, 2008).

Although the pooled results of previous studies on web- and computer-based personalized normative feedback interventions have shown a significant effect on perceived peer drinking norms (Foxcroft et al., 2015), we did not find such an intervention effect. This might be due to the combination of intervention elements derived from different theoretical approaches. Only the web-based part of the intervention provided normative feedback and the text messaging-based part of the intervention primarily addressed outcome expectations, self-efficacy, and planning processes.

The main limitation of the current study was its reliance on self-report and the associated possibility that results may have been influenced by social desirability. Measures used to avoid under- or over-reporting of alcohol consumption included assurance of confidentiality and anonymous assessments conducted via tablet computers and without personal contact, which may have increased the reliability of self-reported data. Another limitation is the lack of stratification of the sample by drinking status prior to random assignment. Although tests for baseline differences on RSOD prevalence and drinking risk group were not significant and we controlled for baseline values within the models, it is possible that the apparent intervention effect or some portion of it was attributable to regression to the mean.

Further limitations included that the effects of the intervention could not be attributed to the web-based part or the text messaging part or their combination, a relatively short follow-up period, with only one assessment 6 months subsequent to baseline assessment, the lack of a

measure of harm associated with RSOD, and limited generalizability because of the inclusion of a convenience sample of school classes willing to participate in the study.

In conclusion, the *MobileCoach Alcohol* programme, a combined web- and text messaging-based intervention, was effective in reducing RSOD prevalence in Swiss upper secondary and vocational school students. Subgroup analyses revealed intervention effects in high risk alcohol users, who also showed beneficial effects including reductions in RSOD frequency and peak blood alcohol concentration. The intervention could be provided to adolescents irrespective of their drinking level because the provision of an individualized primary prevention intervention has several advantages over secondary prevention interventions and because not only problem drinkers seem to benefit from such a program (a tendency towards a protective effect was also found in the low risk drinking group). However, further adequately powered studies are required to determine efficacy in low- and medium-risk drinkers. Due to the high participation rate and the possibility to provide this intervention at relatively low costs, the program provides a viable mean to reduce RSOD for large groups of students within the school setting.

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Table 1: Sample text messages derived from individual data

Risk group	Content category	Individual data considered	Resulting text message
Low risk	Motivation to drink within low-risk limits	Responded ‘Yes’ for the item: ‘If I drink within low-risk limits, other people will respect me.’	Hey Cindy23 You’re right; if you drink alcohol moderately, you will be respected by others, able to control your behaviour, and will not behave like in this Video .
Medium risk	Strategies to resist alcohol in different drinking situations	Individually chosen if-then plan to resist alcohol in a tempting drinking situation (party): ‘When I am at a party, I have soft drinks every now and then.’	Hey Luca. Congratulations! It’s a good decision to have soft drinks every now and then when you are at a party! Non-alcoholic drinks provide your body with important minerals and are a thirst-quenching alternative.
High risk	Local outpatient services for alcohol counselling	Assessment location: Zurich	Hi Robin. Are you concerned about your own alcohol intake or that of a friend? Talking to someone about it can be really helpful. The website www.alcocheck.ch can offer you support. Write an e-mail to info@alcocheck.ch or call 044 444 77.

Table 2: Baseline characteristics of the study sample. Values represent n (%) unless stated otherwise.

Variable	Intervention <i>n</i> = 547	Control <i>n</i> = 494	Total <i>N</i> = 1,041	<i>p</i> ^a
Sex				.49 ^b
Male	264 (48.3%)	229 (46.4%)	493 (47.4%)	
Female	283 (51.7%)	265 (53.6%)	548 (52.6%)	
Age, <i>M</i> (<i>SD</i>)	16.9 (1.6)	16.8 (1.4)	16.8 (1.6)	.83 ^c
Immigration background				.42 ^b
No immigration background	320 (58.5%)	272 (55.1%)	592 (56.9%)	
One parent born outside Switzerland	117 (21.4%)	107 (21.7%)	224 (21.5%)	
Both parents born outside Switzerland	110 (20.1%)	115 (23.3%)	225 (21.6%)	
Education				.41 ^b
Secondary school	489 (89.4%)	445 (90.1%)	934 (89.7%)	
Vocational school	19 (3.5%)	22 (4.5%)	41 (3.9%)	
Technical/high school or university	39 (7.1%)	27 (5.5%)	66 (6.3%)	
Body mass index, <i>M</i> (<i>SD</i>)	21.8 (9.5)	21.5 (7.4)	21.6 (8.5)	.50 ^c
Tobacco smoking status				.01 ^b
Daily smoker	82 (15.0%)	58 (11.7%)	140 (13.4%)	
Occasional smoker	70 (12.8%)	40 (8.1%)	110 (10.5%)	
Former smoker	16 (2.9%)	24 (4.9%)	40 (3.8%)	
Non-smoker	378 (69.1%)	372 (75.3%)	750 (72.0%)	
RSOD, preceding 30 days				.14 ^b
No	289 (52.8%)	283 (57.3%)	572 (54.9%)	
Yes	258 (47.2%)	211 (42.7%)	469 (45.1%)	

RSOD frequency, preceding 30 days, <i>M (SD)</i>	0.7 (1.2)	0.7 (1.1)	0.7 (1.2)	.28 ^d
Number of standard drinks consumed in a typical week in the preceding 30 days, <i>M (SD)</i>	5.5 (8.4)	4.8 (6.9)	5.1 (7.8)	.52 ^d
Peak blood alcohol concentration in the preceding 30 days, <i>M (SD)</i>	1.1 (1.1)	1.0 (1.1)	1.1 (1.1)	.21 ^d
Drinking risk group				.31 ^b
Low	286 (52.3%)	278 (56.3%)	564 (54.2%)	
Medium	181 (33.1%)	142 (28.7%)	323 (31.0%)	
High	80 (14.6%)	74 (15.0%)	154 (14.8%)	
Overestimation of peer drinking norms				.37 ^b
No	307 (56.1%)	291 (58.9%)	598 (57.4%)	
Yes	240 (43.9%)	203 (41.1%)	443 (42.6%)	

^a *p* values for the comparison of the intervention and control groups

^b χ^2 test

^c *t* test

^d *U* test

RSOD: risky single-occasion drinking

Table 3: Intervention effects for dichotomous outcomes

	Intervention (n = 547)			Control (n = 494)			z	p	OR [95% CI]
	Baseline	Follow up	Diff.	Baseline	Follow up	Diff.			
Intention-to-treat analysis									
RSOD, preceding 30 days	258 (47.2%)	226 (41.3%)	-5.9%	211 (42.7%)	224 (45.3%)	2.6%	-2.75	<.01	0.62 [0.44, 0.87]
Overestimation of peer group									
drinking norms	240 (43.9%)	234 (42.8%)	-1.1%	203 (41.1%)	199 (40.3%)	-0.8%	0.39	.69	1.06 [0.79, 1.42]
Complete-cases analysis									
RSOD, preceding 30 days	241 (47.3%)	221 (43.3%)	-4.0%	187 (41.1%)	194 (42.6%)	1.5%	-1.17	.24	0.79 [0.54, 1.17]
Overestimation of peer drinking									
norms	227 (44.5%)	232 (45.4%)	0.9%	193 (42.4%)	182 (40.0%)	-2.4%	1.31	.19	1.22 [0.91, 1.65]

Logistic generalized linear mixed models with group as a fixed factor; school classes as the random intercept; follow-up values as outcomes; and baseline scores, smoking status, educational level and misperception of quantity of peer alcohol consumption at baseline as covariates.

RSOD: risky single-occasion drinking.

Table 4: Intervention effects for continuous outcomes

	Intervention (n = 547)			Control (n = 494)			<i>t</i>	<i>p</i>	<i>d</i> [95% CI]
	Baseline	Follow up	Diff.	Baseline	Follow up	Diff.			
Intention-to-treat analysis									
RSOD frequency, preceding 30 days	0.76 (1.21)	0.69 (0.99)	-0.07	0.68 (1.10)	0.73 (1.05)	0.05	1.31	.19	0.10 [-0.02, 0.23]
Number of standard drinks in a typical week	5.47 (8.43)	4.53 (6.21)	-0.94	4.78 (6.92)	4.41 (5.87)	-0.37	0.55	.58	0.08 [-0.04, 0.20]
Peak blood alcohol concentration	1.10 (1.08)	0.96 (0.93)	-0.14	1.02 (1.08)	0.99 (0.98)	-0.03	1.42	.16	0.12 [0.00, 0.24]
Complete-cases analysis									
RSOD frequency, preceding 30 days	0.74 (1.22)	0.67 (1.02)	-0.07	0.67 (1.14)	0.71 (1.09)	0.04	1.53	.13	0.12 [-0.01, 0.25]
Number of standard drinks in a typical week	5.27 (7.91)	4.59 (6.61)	-0.68	4.70 (6.90)	4.39 (6.11)	-0.31	0.54	.59	0.06 [-0.06, 0.19]
Peak blood alcohol concentration	1.63 (1.78)	0.96 (0.96)	-0.67	1.48 (1.42)	0.99 (1.02)	-0.49	1.42	.16	0.13 [0.01, 0.26]

Linear mixed models with group as a fixed factor; school classes as the random intercept; differences from baseline to follow-up as outcomes; and baseline scores, smoking status, educational level and misperception of quantity of peer alcohol consumption at baseline as covariates

d = Cohen's *d*

RSOD: risky single-occasion drinking

Table 5: Intervention effects for dichotomous outcomes according to baseline drinking risk group (intention to treat analysis)

	Intervention (n = 547)			Control (n = 494)			z	p	OR [95% CI]
	Baseline	Follow up	Diff.	Baseline	Follow up	Diff.			
RSOD, preceding 30 days									
Low risk	0 (0.0%)	48 (16.8%)	16.8%	0 (0.0%)	59 (21.2%)	21.2%	-1.959	.051	0.64 [0.41, 1.00]
Medium risk	179 (98.9%)	117 (64.6%)	-34.3%	137 (96.5%)	97 (68.3%)	-28.2%	-0.97	.33	0.76 [0.44, 1.31]
High risk	80 (100.0%)	61 (76.3%)	-23.7%	74 (100.0%)	68 (91.9%)	-8.1%	-1.99	.047	0.29 [0.09, 0.98]
Overestimation of peer drinking norms									
Low risk	122 (42.7%)	128 (44.8%)	2.1%	112 (40.3%)	109(39.2%)	-1.1%	1.06	.29	1.24 [0.83, 1.84]
Medium risk	83 (45.9%)	76 (41.9%)	-4.0%	52 (36.6%)	58 (40.8%)	4.2%	-0.12	.91	0.97 [0.58, 1.64]
High risk	35 (43.8%)	30 (37.5%)	-6.3%	39 (52.7%)	32 (43.2%)	-9.5%	-0.46	.64	0.84 [0.40, 1.76]

Logistic generalized linear mixed models with group as a fixed factor; school classes as the random intercept; follow-up values as outcomes; and baseline scores, smoking status, educational level and misperception of quantity of peer alcohol consumption at baseline as covariates

RSOD: risky single-occasion drinking

Table 6: Intervention effects for continuous outcomes according to baseline drinking risk group (intention to treat analysis)

	Intervention (n = 547)			Control (n = 494)			<i>t</i>	<i>p</i>	<i>d</i> [95% CI]
	Baseline	Follow up	Diff.	Baseline	Follow up	Diff.			
RSOD frequency, preceding 30 days									
Low risk	0 (0.0)	0.25 (0.52)	0.25	0 (0.0)	0.29 (0.78)	0.29	-0.77	.44	0.06 [-0.11, 0.23]
Medium risk	0.98 (0.39)	1.03 (1.05)	0.05	0.89 (0.39)	0.95 (0.79)	0.06	1.01	.31	0.02 [-0.20, 0.24]
High risk	2.99 (1.57)	1.51 (1.30)	-1.48	2.81(1.15)	1.95 (1.26)	-0.86	2.59	.01	0.34 [0.02, 0.66]
Number of standard drinks in a typical week									
Low risk	0.98 (1.72)	2.01 (3.55)	1.03	1.09 (1.84)	2.01 (3.82)	0.92	-0.21	.83	-0.03 [-0.20, 0.13]
Medium risk	7.08 (6.92)	6.14 (6.22)	-0.94	6.65 (5.54)	5.39 (4.18)	-1.26	-0.99	.33	-0.04 [-0.26, 0.18]
High risk	17.85 (11.71)	9.90 (8.63)	-7.95	15.07 (9.24)	11.53 (8.24)	-3.54	1.62	.11	0.37 [0.05, 0.68]
Peak blood alcohol concentration									
Low risk	0.27 (0.31)	0.48 (0.56)	0.21	0.27 (0.30)	0.53 (0.69)	0.26	0.91	.37	0.08 [-0.09, 0.25]
Medium risk	1.91 (0.89)	1.41 (0.94)	-0.50	1.86 (0.96)	1.33 (0.84)	-0.53	-0.42	.67	-0.03 [-0.25, 0.19]
High risk	2.24 (0.82)	1.66 (1.02)	-0.58	2.22 (0.91)	2.08 (1.03)	-0.14	2.18	.03	0.38 [0.06, 0.70]

Linear mixed models with study group as a fixed factor; school classes as the random intercept; differences from baseline to follow-up as outcomes; and baseline scores, smoking status, educational level and misperception of quantity of peer alcohol consumption at baseline as covariates

d = Cohen's *d*

RSOD: risky single-occasion drinking

Figure captions

Figure 1: Participants' progress through the trial

Figure 2: Risky single-occasion drinking prevalence by study condition and drinking risk group based on intention to treat analysis. *Significant difference between intervention and control group with $p < .05$



