Nudging construction workers towards better sun-safety behaviour: summary of the evidence for practitioners

Abstract

Excessive exposure to solar ultra-violet (UV) radiation can cause skin cancer, but inadequate exposure to sunlight limits the production of vitamin D. We report a text messaging and supportive smartphone app intervention to reduce UV exposure in the summer and promote vitamin D intake in winter. Results suggest that many workers had insufficient circulating vitamin D in winter, but for the intervention group vitamin D levels increased significantly compared to the control group. In summer, workers were exposed to relatively high UV levels, which were sufficient to importantly increase their risk skin cancer. The sun-safe intervention failed to reduce exposure to solar UV, which we attribute to an entrenched belief that a suntan is desirable. We argue that a more prescriptive risk-based approach is needed to reduce the risk of skin cancer among outdoor construction workers.

Abstract: 136 words

Text: 3114 words

Introduction

Excessive exposure to solar ultra-violet (UV) radiation can cause skin cancer. However, inadequate exposure to sunlight limits the production of vitamin D. There is very little research on understanding the barriers to adopting sun-safe behaviours in the workplace and encouraging behaviours that ensure vitamin D sufficiency.

In Britain each year there are almost 3,000 cases of non-melanoma skin cancer caused by exposure to UV radiation from the sun at work and around 250 cases of malignant melanoma (Rushton et al. 2012; Rushton and Hutchings 2017). Many adults, in particular of African-Caribbean and Asian descent living in Britain, are deficient in vitamin D, which may result in bone pain and osteoporosis (Ford et al. 2006). Low vitamin D has also been linked with increases in the risk of some cancers, cardiovascular diseases, metabolic disorders, infectious diseases and auto-immune diseases, although the evidence for causal association is still uncertain (PHE 2017). There is no evidence of the extent of vitamin D insufficiency among outdoor workers in the Britain.

Communicating information about sun-safety is complicated in Britain because while workers need to minimise their sun exposure during summer months, this will reduce the production of vitamin D. In winter months they cannot get sufficient UV exposure to synthesise the vitamin D necessary for health and the main source during these periods is through their diet, e.g. fish oils, eggs or supplements (PHE 2017). The message for sun-safety needs to be tailored to outdoor conditions in a way that is impossible in a single training intervention. One option is to use mobile phone short messages (SMS), along with supportive information, to communicate these complex messages. Mobile phone SMS messages have been shown to be

effective in health promotion intervention studies (Montes et al. 2012; Wong et al. 2013; Armanasco et al. 2017). To date, there are only a small number of research studies that have investigated SMS messaging in relation to skin cancer risks. Hingle et al. (2014) studied the effect of text messages on sun protection and skin self-examination among children in the USA, showing statistically significant increases in self-reported sunscreen use, wearing a hat and sunglasses and finding shade around midday. Youl et al. (2015) studied adults in Australia and also found that messages were effective in inducing protective behaviour and in encouraging self-examination for skin cancer. These studies suggest the use of SMS messaging may be an appropriate way to tailor sun-safety and vitamin D messages for construction workers in Britain.

Aims and Objectives

The aim of the project was to investigate whether the combination of short messages delivered to the smartphones of construction workers and appropriate organisational support, such as the provision of vitamin D supplements or sunscreen, can influence workers' behaviour to reduce exposure to UV radiation among those at risk of excessive exposure, and increase exposure or promote appropriate dietary changes among those who are likely to receive insufficient sun exposure to synthesise vitamin D. The aim was to influence behavioural choices of workers to help them make better sun-safety choices, which in psychological theory is often referred to as a "nudge".

The study involved five key objectives:

- to devise a way of delivering short messages to the smartphones of construction workers, to change behaviour to minimise the risk of skin cancer and maximise the health benefits of vitamin D generated from solar UV radiation and diet;
- to develop a sun-safe and healthy mobile phone app that could be used more widely in the construction sector;
- to conduct an experimental trial to demonstrate that the intervention delivers safe and healthy outcomes, based on measured serum vitamin D levels across the course of a year;
- to use personal UV monitors to provide evidence of altered personal behaviour as a result of the intervention;
- to develop a model strategy to change personal behaviour using smartphone technology, which could be widely applied in a workplace setting.

Methods

The study protocol has been published in the scientific literature (Nioi et al. 2018). The development of the study methodology and the measurement is briefly summarised below. Ethical approval to carry out this research was granted by Heriot-Watt University Engineering and Physical Sciences Ethics Committee (approval number 2016-164). A detailed report of the study is available from https://www.iosh.co.uk/Books-and-resources/Nudging-construction-research.aspx

At the start of the project we issued a press release to raise awareness of the forthcoming research. Three large construction companies were contacted to get support for the project (BAM Nuttall Ltd, Laing O'Rourke, and Bovis Homes). Additional construction companies were

identified via a networking event at the Health in Construction Leadership Group (http://www.healthinconstruction.co.uk/about_us), utilising the research network with IOSH, and by contacting key health and safety professionals at large companies with active construction sites in central Scotland and southern England. Nine sites were eventually included in the study (five in Scotland and four in Greater London).

A smartphone application (mobile app) was developed to provide study participants with general information and guidance about UV exposure, sun-safety, dietary health advice and the daily UV Index (UVI) forecast for the user's locality. A third-party SMS delivery service (www.Textmarketer.co.uk) was used, through a web-based interface, to send bulk SMS to multiple recipients. Questionnaires were developed by the researchers to assess workers' beliefs about sun-safety and healthy eating in relation to increasing vitamin D levels within the psychological paradigms of the Theory of Planned Behaviour (Ajzen, 1985) and Stages of Change (Prochaska & DiClemente, 1983), and knowledge about sun-safety and vitamin D.

Researchers met with representatives from the companies and their workers to explain details of the study and the expectation from participants. All participants at a site were initially allocated to either receive the intervention or not. Recruitment was for three waves of data collection – two low-UV exposure periods and one high-UV exposure period, with each study period lasting 21 days. At the second and third waves the sites that had not received the initial intervention then had the intervention and vice versa. Where it was not possible to retain the same participant at a site between waves, due to leaving the job or some other reason, a substitute participant was recruited. Between 56 and 61 workers were studied at each wave.

The intervention was delivered to the workers via the mobile phone SMS. A message was sent to participants on each workday, tailored to reflect the season, encouraging them to boost vitamin D levels during periods of low UV and to pay attention to sun-safety during periods of high UV (Example text messages are shown in Table 1). The supportive phone app contained information about sun-safe actions and sources of vitamin D. During the low-UV intervention period, participants were issued with a vitamin D dietary supplement (daily 10µg) and advised that, if they wished, they could take these during the three-week study period. The number of supplements consumed during the study was recorded at the follow-up visits. During the control periods participants did not receive the intervention daily text messaging service or prompts to view the sun-safe and healthy behaviour app.

The main outcome measure was the concentration of vitamin D in blood samples (25-hydroxy vitamin D or 25(OH)D) measured by high-performance liquid chromatography by the Pathology Department, City Hospital, Birmingham (www.cityassays.org.uk). Samples were collected from each worker at the start and end of each wave. Participants were sent their results via email, which were classified as 'Severe Deficiency' (<15 nmol/l), 'Deficiency' (15-30 nmol/l), 'Insufficiency' (30.1-50 nmol/l), or 'Adequate' (>50.1 nmol/l). During the high-UV period participants were issued with a UV wearable sensor mounted on the rear of their hard hat. These sensors, which were calibrated by the supplier, logged UV measurements throughout a working day (08:00 – 17:00). The data were summarised as standard erythemal dose (SED) measures over an 8-hour day. The SED is a measure of exposure that is independent of skin type and is equivalent to 100 J/m^2 of erythemally weighted radiant exposure.

For each wave, differences between start and end levels of vitamin D were calculated for each participant. Comparison of change in 25(OH)D between the intervention group and the control group used a two-group t-test to determine whether there was a statistically significant difference between the two groups. Levels of change in 25(OH)D were also examined in relation to responses to the questionnaires, using multiple linear regression methods. These analyses were carried out separately for each of the three waves of data collection. Some analysis of data collected in the winter period (Waves 1 and 3) was carried out for individuals during their earliest participation in the study, i.e. Wave 1 participants plus participants in Wave 3 who had not attended Waves 1 or 2.

Results

Data were collected over three waves: two in winter and one during summer. At Wave 1, eight sites participated in the study (five in Scotland and three in London), in Waves 2 and 3, nine sites participated (five in Scotland and four in London). From the original cohort, 61% of participants returned to participate in Wave 2 of data collection and 40% of participants completed all three waves of data collection. Details of the participants are shown in Table 2.

Around half of the workers taking part in the study had insufficient circulating 25(OH)D in their blood during winter. A small proportion of the participants were either 'deficient' or 'severely deficient' during winter (15% at the start of Wave 1 and 8% in Wave 3) and three participants were 'deficient' in the summer period. During the winter study periods vitamin D levels in the intervention group were significantly higher after the intervention: from 48% with sufficient levels to 88% in the first winter period (Wave 1) and from 52% to 70% in the

second period (Wave 3). The differences between the Control and Intervention groups were statistically significant in Waves 1 ($p<0.05$) and of borderline statistical significance in Wave 3 ($p=0.053$). These results suggest daily information and availability of a dietary vitamin D supplement is likely to increase 25(OH)D levels during periods when UV is too low to be synthesised naturally.

During the summer study period the study failed to show a decrease in 25(OH)D levels in the intervention group as hypothesised; in fact, levels were statistically significantly higher in the intervention group ($p<0.05$). Measurements confirmed that UV exposure was higher in the intervention group than the control group. In the questionnaire responses most workers expressed the view that 'I like to have a sun tan,' and this may be the main reason for the lack of appropriate behaviour change from the intervention. These results suggest that a more sustained risk-based management approach is needed to change sun-safe behaviours on construction sites.

As expected, external UV dose estimates were generally higher at the southern sites compared to the northern ones. However, at each wave the median and mean blood 25(OH)D levels were higher in the north. This may reflect differences in skin colour or some other aspect of the work, for example time spent outdoors. This is the first research study to measure UV exposure among outdoor workers in Britain. We found that in summer, construction workers who predominantly worked outdoors were exposed to on average 2.0 SED and those who worked partly indoors and partly outdoors had 0.69 SED UV exposure. For outdoor workers, around 40 per cent of the daily UV exposures exceeded 2.0 SED while about 12 per cent of the exposures for the indoor workers were above 2.0 SED.

Knowledge of sun-safety measures and steps to increase vitamin D improved in both the control and intervention groups across the study periods. However, the desirability of having a sun tan remained high, and more effort is needed to improve knowledge of the risks and attitudes to sun tanning, which is a sign of skin damage.

Beliefs around perceptions of control to increase vitamin D were higher in the intervention group during the low-UV (winter) periods – that is, workers intended to take steps to improve their vitamin D intake during the winter. Participants also felt less social pressure to increase vitamin D, suggesting the information delivered equipped them to change beliefs. Similarly, in the high-UV (summer) period, the intentions to take sun-safe measures were higher in the intervention group.

The intervention also showed positive effect on desirable behaviours in the first low-UV period (winter). The intervention group reported more contemplation of consuming of vitamin D-rich products and by follow-up at the second winter this had changed from contemplation to preparation. In the high-UV period (summer) the intervention group reported more actively wearing sunglasses for UV protection.

Discussion

This study highlights the pivotal role that the construction industry should play in leading sun-safety on-site and in taking an initiative on workforce health and wellbeing related to vitamin D. The research demonstrates the potential of delivering health information via text messaging and how this approach could serve to promote sun-safety behaviours during the

summer months and help to reduce the decline in vitamin D levels during the winter period. Text messaging was considered an appropriate way to deliver a daily “nudge” message to the workers that was tailored to the situation and the level of knowledge and awareness of the workers. This was supplemented with an informative mobile phone app to enable workers to access more detailed information to help them make appropriate health and safety choices. This methodology is applicable to managing other risk where it is important to influence worker behaviour and in sectors beyond construction.

During the summer, workers in the study experienced relatively high UV levels from the sun. Epidemiological studies among outdoor workers have shown a clear increased risk for both squamous cell carcinoma (SCC) and basal cell carcinoma (BCC), which are the main forms of nonmelanoma skin cancer. There are few studies that have quantified the risk of skin cancer in relation to exposure. However, a recent SCC case-control study from Germany estimated UV exposure using a job-exposure matrix (Schmitt et al. 2018). They found a doubling of the risk for SCC for a lifetime occupational exposure of 6,348 SED. For someone who worked in an outdoor construction job for 45 years that would correspond to an annual exposure of around 140 SED or around 1.5 SED on working days when there was potential exposure to solar radiation, i.e. late spring to early autumn. In our study almost half of the outdoor workers exceeded this level during the summer monitoring and over a working life these exposures would importantly increase the risk of skin cancer.

Disappointingly, the intervention did not reduce solar UV exposure or 25(OH)D levels in summer, as was originally hypothesised. The main reason for this seems to be a deeply entrenched perceived benefit of sunlight and a sun tan among the British population.

Currently sun-safety is generally seen as an issue of personal choice for workers with the role of the employer being to promote good practice. The guidance from HSE emphasises employers should provide training, 'encouraging' workers to cover up and use sunscreen, and to 'consider' organising work to minimise exposure. Health surveillance is left to the discretion of workers. The general impression is that this is a public health issue rather than a health and safety risk that requires active management. However, we suggest the regulator should provide a stronger role in promoting a risk-based management approach to UV exposure, which we believe is already required under the provisions of the Management of Health and Safety at Work Regulations. In our opinion, health surveillance of outdoor workers to detect skin cancer is already a legal obligation on employers.

In Britain over the last 40-years, the construction industry has made great strides in reducing the toll of deaths and injuries from workplace accidents. Over this period the rate of fatal accidents reduced from around 9 per 100,000 in the 1980s to 1.6 per 100,000 in 2017/18 (HSE, 2018). However, the priority has been overwhelmingly towards safety and there has been proportionately little effort in dealing with the manifest health issues in the industry, particularly from work-related cancers and lung disease. The recent introduction of the Health in Construction Leadership Group (www.healthinconstruction.co.uk) shows that there is a will to refocus on important health challenges, one of which should be sun-safety. The efforts of practitioners in this sector could have an important impact in changing attitudes to UV exposure, reducing skin cancer risks and improving vitamin D status of the workforce.

A high proportion of workers in our study had insufficient circulating 25(OH)D in winter, which is common in the UK, but is rather unexpected in an outdoor working population. The

intervention had a positive impact on vitamin D levels during the winter, which increased significantly in comparison to the control group. Employers could make important contributions to tackling this issue through health promotion campaigns at work, which will benefit the health and wellbeing of their workforce. From our research there is a lack of knowledge about vitamin D among construction workers and many are not yet ready to act to increase their vitamin D intake. Information campaigns and support in the workplace by providing options to consume food fortified with vitamin D or vitamin D supplements would provide further health benefit.

This study provides important information about the effectiveness of a technology-based intervention to promote sun-safe and healthy behaviours. It demonstrates that text messaging and a supportive app can be an easy and accessible method of communicating health and safety messages to workers. The method could easily be extended to address other health and safety issues where personal behaviour is important, e.g. manual handling, and to workers outside construction. Importantly, it is suggested that a more prescriptive risk-based approach is needed to reduce the risk of skin cancer among outdoor construction workers. This could be achieved by employers mandating risk management measures, such as appropriate clothing and work scheduling, to protect workers from solar UV exposure and enforcing the use of these measures.

Practice points

The study is summarised in the infographic shown in Figure 1.

This research highlights several issues that practitioners should consider:

- health promotion initiatives to “nudge” workers towards healthier dietary choices, including dietary supplements over winter, to boost serum 25(OH)D levels in their workers.
- sun-safety remains a low priority on construction sites and awareness of current sun-safe measures is low. Employers should adopt a risk-based approach to manage exposure to solar UV proactively, in which risk management measures should be prescribed and the use of these measured enforced.
- provide health surveillance to detect skin cancers among outdoor workers because of the likely high UV exposure and the consequent increased risk of skin cancer
- nudging messages can be easily delivered via text messages or location-driven phone apps to help a workforce stay safe in the sun.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was funded by the Institution of Occupational Safety and Health (IOSH) (http://www.iosh.co.uk/NTTL/Home/About-NTTL.aspx).

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Figure 1: Nudging construction workers towards better sun safety behavior infographic

Table 1 Example text messages sent to participants

Introductory texts sent at the start of the intervention wave

Hi- this is Sunny D, thanks for helping in the Heriot-Watt uni study. You'll receive messages from me over the next 3 weeks on works days only.
Hi- this is Sunny D, thanks for helping in the Heriot-Watt uni study. You'll receive messages from me over the next 3 weeks on works days only. I'll send you a text soon so you can download the app on Android or view the website if you're on iPhone :)
Hi {FirstName}, check out this video our funder IOSH made about working safely in the sun https://www.youtube.com/watch?v=i1vEuLdOgnw

Spring messages

We are finally into Spring! That means the days are longer and the sun is warming up. It's time to starting thing about sun safety at work.
Do you know your skin type? Light coloured skin burns more easily. Make sure to protect yourself – check our app for tips!
Sunburn puts you at risk of developing skin cancer. Protect yourself with sunscreen, cover with clothing & seek shade

High summer messages

Sun tanning ages skin and puts you at risk of skin cancer – see our app for info on sun-safety
Do you know your skin type? Light coloured skin burns more easily. Make sure to protect yourself – check our app for tips!
The UV Index is high today. Remember your sunscreen. Check the app for more info on sun protection advice

Low summer messages

We are coming to the end of summer - don't be fooled some days the UV Index is still high. Check the weather in advance and apply sunscreen if you need too!
Sunburn puts you at risk of developing skin cancer. Protect yourself with sunscreen, cover with clothing & seek shade
Its not only you who suffers if you develop skin cancer – what about your family? Protect yourself from the sun.

Vitamin D messages

A good way to boost your Vitamin D is eating oily fish!
Been eating more oily fish and eggs to boost your Vitamin D, well done!
Did you know there are diary-free alternatives that are fortified with vitamin D? Try Alpro Soy Milk or Oatmeal milk!

A full list of messages sent to participants can be found in the report of the study, available at https://www.iosh.co.uk/Books-and-resources/Nudging-construction-research.aspx

Table 2 Description of study participants, percentage (number)

Variable	Wave 1 (8 sites)	Wave 2 (9 sites)	Wave 3 (9 sites)
Age (years)			
18–30	21.4% (12)	31.2% (19)	34.4% (21)
31–50	57.1% (32)	47.5% (29)	47.5% (29)
51–65	21.4% (12)	21.3% (13)	18.0% (11)
Gender			
Male	96.4% (54)	96.7% (59)	88.5% (54)
Female	3.6% (2)	3.3% (2)	11.5% (7)
Ethnicity			
White UK/Irish	82.1% (46)	73.8% (45)	75.4% (46)
Asian/Asian British	1.8% (1)	4.9% (3)	6.6% (4)
Black/African/Caribbean/Black British	5.4% (3)	3.3% (2)	4.9% (3)
Other	10.7% (6)	18.0% (11)	13.1% (8)
Skin type			
Very pale	-	1.6% (1)	1.6% (1)
Fair/pale	35.7% (20)	29.5% (18)	34.4% (21)
Fair/beige	42.9% (24)	34.4% (21)	34.4% (21)
Olive/light brown	16.1% (9)	31.1% (19)	26.2% (16)
Dark brown	-	-	1.6% (1)
Black	5.4% (3)	3.3% (2)	1.6% (1)
Occupation			
On-site operative	59.1% (33)	53.9% (33)	39.3% (24)
On-site professional	37.7% (21)	40.9% (25)	46% (28)
Other	3.6% (2)	4.9% (3)	14.8% (9)
Total	56	61	61