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1 **Vitamin D_3 content of cows' milk produced in Northern Ireland and its efficacy as a**
2 **vehicle for vitamin D fortification: a UK model**

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35 **Abstract**

36 Cows' milk is a relatively poor source of vitamin D but figures listed in UK food composition 37 tables may be outdated. Samples of milk were collected for 1-year and vitamin D_3 38 concentrations analysed using HPLC. Milk consumption data were obtained from the National 39 Diet and Nutrition Survey (Years 1-4). A theoretical model applied vitamin D_3 fortifications of 40 1µg, 1.5µg and 2µg/100g to simulate improvements in vitamin D intakes. Mean±SD vitamin D_3 41 in whole milk was 0.06±0.02µg/100g. No seasonal differences were apparent. Fortification of 42 cows' milks with 1µg, 1.5µg and 2.0µg/100g, theoretically increased median vitamin D intakes 43 from 2.0µg/day to 4.2µg, 5.1µg and 5.9µg/day, respectively. Higher vitamin D_3 in milk from 44 this study than that currently in food composition tables, suggests further analysis is warranted. 45 This model suggests vitamin D fortification of cows' milk is an effective strategy to help more 46 of the population achieve recently revised RNIs for vitamin D.

47

48 **Keywords:** Vitamin D; fortification; cows milk; food composition; dietary intake; model; 49 NDNS

Introduction

Vitamin D plays an essential role in the metabolism of calcium by increasing its absorption in the small intestine (COMA 1991) and for this reason vitamin D has an important role to play in musculoskeletal health (Lanham-New 2008; Pojednic & Ceglia 2014; Todd et al. 2015). Vitamin D deficiency has been known for many years to be a factor in sub-optimal bone health and to lower bone mineral density (Thacher & Clarke 2011). Moreover, poor vitamin D status has been more recently associated with many other non-skeletal chronic conditions such as cardiovascular disease, certain cancers, decline in cognitive function, type II diabetes, and rheumatoid arthritis (Martini & Wood 2009; Kostoglou-Athanassiou et al. 2012; Autier et al. 2014; Feldman et al. 2014). Vitamin D insufficiency (25-hydroxyvitamin D [25(OH)D] concentration of <50nmol/l) and deficiency (25(OH)D concentrations of <25nmol/l) (IOM 2011) are prevalent, with an estimation that 1 billion people could be classed as insufficient or deficient worldwide (Holick 2007). The Irish Adult Nutrition Survey (NANS), reported that approximately one third of adults aged 18–84 y were classed as vitamin D insufficient during the summer, while in the winter this increased to over half of the adult population (IUNA 2011; Cashman et al. 2013). Similar findings regarding vitamin D insufficiency have been noted in the UK National Diet and Nutrition Survey (Public Health England 2014).

The majority of vitamin D required by humans is derived by ultraviolet (UV)-B radiation of the 7-dehydrocholesterol in the skin (COMA 1991; Webb & Holick 1988), although a number of factors negatively influence the skin's ability to synthesise the vitamin (Hagenau et al. 2009). Such factors include increasing age, skin pigmentation, clothing, sedentary/indoor lifestyles, the use of sun protection and geographical location (i.e. latitude). It has been long established that the northerly latitude of the UK and Ireland [50-60°N] means UVB intensity is inadequate to promote the dermal synthesis of vitamin D during the winter months (approximately October-March) (Webb et al. 1998; Hill et al. 2008), causing the population to be solely reliant on dietary sources during this time to maintain the body's stores of the vitamin. Despite this reliance on dietary sources, previous literature from the UK and Ireland more often than not report low intakes of vitamin D (<5μg/d), because naturally occurring food sources are so limited (IUNA 2011; Public Health England 2014). More worryingly, these figures are considerably lower than the revised reference nutrient intake (RNI) suggested by the Scientific Advisory Committee on Nutrition (SACN) of 10μg/d of vitamin D daily for the general population aged 4+ y (or the safe intake 10μg/d for children aged 1-4 y) (SACN 2016).

83 Fortified foods are increasingly contributing to the dietary intake of the population,
84 especially in those who do not also consume dietary supplements (Black et al. 2012).
85 Although milk and dairy products are sources of naturally occurring vitamin D (McCance &
86 Widdowson 2002; BDA 2007), without fortification, the vitamin D content of milk is minimal
87 and has also been known to vary considerably from winter to summer (Kurmann & Indyk
88 1994; Jakobsen & Saxholt 2009). '*The Composition of Foods*' series by McCance and
89 Widdowson (2014) provides extensive nutritional data on a number of foods. Although these
90 tables have been updated several times since their inception, the most recent 7th edition
91 (published in 2014), has reported the lowest vitamin D content for whole, semi-skimmed
92 and skimmed milk (i.e. as trace) compared to earlier editions, based on limited sampling.
93 One possible strategy to increase vitamin D intakes within the population is through the
94 fortification of milk, which is a staple dietary component for a large proportion of the UK and
95 Irish population. In Canada, the fortification of liquid milk is mandatory at concentrations
96 ranging from 0.875µg–1.125µg/100ml (IOM 2011). Indeed, numerous studies have reported
97 the effectiveness of dairy fortification in increasing vitamin D intake in other countries (Calvo
98 et al. 2004; Harika et al. 2016; Jaaskelainen et al. 2017). Within the UK, however, mandatory
99 fortification with vitamin D is limited to a few foods only, including margarine, energy-
100 restricted foods for diets intended for weight loss and infant formula (Hypponen & Power
101 2007; Allen 2015). Vitamin D is only added to a small number of other foods at the discretion
102 of the food industry (e.g. yogurts, cereals and breads).
103 Owing to the low dietary intakes previously reported, and the relatively low uptake of food
104 fortification in the UK/Ireland, alternative food-based strategies to improve consumers'
105 vitamin D intakes, and status are warranted. Therefore, the aims of the current study are to,
106 (1) determine the concentrations of vitamin D_3 in cows' milk produced in Northern Ireland
107 (NI), and; (2) simulate how fortification of cows' milk could theoretically improve overall
108 dietary vitamin D intakes of the UK population using a dietary modelling scenario.

109 **Materials and methods**

110 ***Study samples***

111 The sampling protocol was designed to be representative of cows' milk on retail sale in
112 NI. Monthly 1L samples of raw and whole pasteurised milk (standardised to a minimum
113 fat content of 3.5%) were collected for a period of 1 year (May 2013 – May 2014) from two
114 dairy processors. All milk samples were collected by staff based within the processing

115 plants. Raw milk samples were collected immediately pre-pasteurisation. Owing to the well
116 documented seasonal variation in vitamin D content, milk samples collected during October–
117 March are referred to as winter milk, while those samples collected between April and
118 September are referred to as summer milk hereafter. Samples were stored at -20°C prior to
119 analysis. Quantification of vitamin D_3 content in stored samples were analysed by HPLC
120 (Agilent 1200 Series) (method adapted from Trenerry et al. (2011). Samples were run with a
121 99% acetonitrile: 1% methanol mix at a rate of 1.5ml per min for 50mins. Vitamin D_3 was
122 quantified at the 265/280 wavelengths.
123
124 ***Population dietary data***
125 The NDNS Rolling Programme Years 1-4 (2008/09–2011/12) dataset was used to provide
126 nationally representative data on both current vitamin D intakes (μg/d) and typical milk
127 consumption (g) of the UK population (UK Data Service 2014). The dataset comprises of 3-
128 or 4-d food diaries from 4,156 individuals [2,174 adults (18–94 y) and 1,982 children (1.5–
129 17 y)]. Consumption of whole, semi-skimmed, skimmed and 1% milks were included in the
130 current analysis. The theoretical impact of vitamin D fortification was evaluated for the
131 entire study population and by age group [children (1.5-17 y old and adults (≥18 years)].
132 Attention was also given to sub-groups considered to be at-risk of vitamin D deficiency:
133 young children (aged 1.5–3 y); adults over the age of 65 y (COMA 1991); women of
134 childbearing age (16–49 y) (Public Health England 2014).

135 ***Dietary modelling***

136 The vitamin D content of milk as listed in the McCance and Widdowson (2002) was used
137 in the most recent NDNS analysis and therefore acted as the baseline for the current
138 dietary model. Vitamin D fortification concentrations of 1μg/100g, 1.5μg/100g and
139 2μg/100g were selected based on the American and Canadian fortification levels and
140 those of enriched ‘super-milks’ which are commercially available in the UK and Ireland.
141 These fortification concentrations were then applied to the consumption of whole, semi-
142 skimmed, skimmed and 1% milk to estimate the effect fortification at these concentrations
143 would have on the overall vitamin D intakes of the population. As part of this dietary model,
144 the current tolerable upper limits (UL) for daily vitamin D intake were considered to
145 determine if the fortification scenario would subsequently give rise to consumer intakes
146 exceeding the UL. The ULs used were those provided by European Food Safety Authority

147 (EFSA) at 100μg/d for individuals aged 11+ y, 50μg for children between 1 and 10 y, and
148 25μg for infants <1 y (EFSA 2012).

149 ***Statistical analysis***

150 The Statistical Package for the Social Sciences (IBM SPSS Statistics 22, Chicago, IL,
151 USA) was used for analysis of all data. Values of $P<0.05$ were regarded as statistically
152 significant throughout. Normality of the data was assessed using Kolmogorov-Smirnov tests,
153 and where data could not be normalised, the results are expressed as medians (25th and 75th
154 percentiles). Descriptive statistics and t-tests were used to describe the study sample and to
155 compare the concentrations of vitamin D present within the different forms of milk between
156 seasons (summer and winter) and between milk types (raw and pasteurised whole) and to
157 compare intakes to the current reference nutrient intake (RNI) (SACN 2016) and tolerable UL
158 (EFSA 2012). The comparison of vitamin D intakes at baseline and post-fortification were
159 tested using non-parametric tests, Wilcoxon Signed Rank test.

160 **Results**

161 ***Vitamin D analysis of milk***

162 The average year-round mean ± SD vitamin D_3 content of Northern Irish raw and
163 pasteurised whole milk collected as part of this study was 0.08 ± 0.04μg/100g and 0.06 ±
164 0.02μg/100g respectively, with a range of 0.01–0.16μg/100g for raw milk (Figure 1) and 0.03–
165 0.12μg/100g for pasteurised whole milk (Figure 2). The mean ± SD vitamin D_3 content per
166 100g between summer vs. winter milk was not significantly different for either raw (0.07 ±
167 0.03μg vs. 0.08 ± 0.04μg per 100g; P=0.479) or pasteurised whole milk (0.07 ± 0.03μg vs.
168 0.05 ± 0.01μg per 100g; P=0.227). A significant difference was noted when comparing the
169 vitamin D_3 content of raw and pasteurised whole milk throughout the year (P=0.037). When a
170 seasonal comparison of the vitamin D_3 content of raw and pasteurised whole milk was
171 investigated, a significant difference was noted in winter (P=0.033) but not in summer
172 (P=0.506).

173 ***NDNS data***

174 A total of 16,539 recorded dietary days were available for analysis from the raw NDNS
175 dataset [32] of which, 13,962 dietary days (84.4%) reported an intake of milk. Survey

176 population data can be found in Table 1. Daily milk intakes (portion size per eating
177 occasion) ranged from 2.5g to 2850g. On average, a larger portion size of whole milk was
178 consumed compared to the other three milk types (Figure 3). Semi-skimmed milk was the
179 most commonly consumed milk (Figure 4) in the total study population (53.1% of dietary
180 days). A higher proportion of children (aged 1.5 to 17 y) were consumers of whole milk
181 compared to adults ($P<0.001$), and the opposite was true for the other three milk types;
182 however, significant difference was only seen in skimmed milk consumption $P<0.001$ (semi-
183 skimmed $P=0.509$; 1% fat $P=0.505$) (Figure 4).

184 Mean dietary vitamin D intake at baseline for the entire study population was 2.50µg/day
185 (SD 1.87) with a range of 0.00–20.96µg (Table 2). Mean daily vitamin D intakes were
186 significantly higher for males compared to females (2.71 ± 2.09µg vs. 2.31 ± 1.65µg;
187 $P<0.001$). Adults also had a significantly higher daily vitamin D intake compared to
188 children (2.92 ± 2.13µg vs. 2.04 ± 1.42µg; $P<0.001$). Baseline vitamin D intakes in at-risk
189 groups are shown in Table 3 and also increased with age.

190 ***Dietary modelling scenario***

191 Of the 4,156 individuals surveyed as part of the NDNS, only 37 (0.89%) met the new
192 RNI of 10µg/d, but following the fortification scenario applied in this dietary model these
193 figures increased. When a fortification of 2µg/100g was applied 511 (12.29%) of the study
194 population achieved the new RNI (Table 2).

195 Prior to applying the fortification scenario, six women of childbearing age (0.74%) met
196 the RNI of 10µg/d (SACN 2016), following theoretical fortification at 2µg/100g this figure
197 increased to 41 (5.04%) participants. The same increase was seen in those over 65 y, with a
198 total number of individuals reporting an intake of 10µg/d or above increasing from seven
199 (1.65%) to 76 (17.76%). The greatest effect of fortification was seen in children (aged 1-3
200 y). At the highest fortification, 99 (25.65%) children would be meeting their recommended
201 intake, compared to baseline where only eight (2.12%) were meeting recommended intakes.
202 Up to the highest fortification (2µg/100g), no participants exceeded the age-specific
203 tolerable UL (EFSA 2012), either in the total population (Table 2) or in at-risk groups (Table
204 3).

205 When looking at diary days, fortification was shown to increase the vitamin D intake of
206 the entire population with median intakes increasing from 2.3µg/d to 6.1µg/d for semi-
207 skimmed milk. For whole milk a similar increase was seen, with a median intake of 1.8µg/d

208 at baseline and 7.4μg/d following fortification at the highest concentration (2μg/100g).
209 The effect of simulated fortification at each concentration is shown in Table 4, and
210 fortification at all three concentrations (1μg, 1.5μg and 2μg per 100g) resulted in
211 significantly increased vitamin D intakes for all milk types (P<0.001).

212 **Discussion**

213 Results from this study clearly demonstrate that a vitamin D fortification policy for milk
214 could potentially help increase the percentage of the population (>12%) achieving the revised
215 RNI/safe intakes of 10μg/day vitamin D (SACN 2016). Moreover, even with the highest
216 fortification scenario (2μg/100g), no participant within the current fortification model had a
217 vitamin D intake that exceeded EFSA's tolerable UL (100μg/d for 11+ y; 50μg/d for 1-10 y)
218 (EFSA 2012), suggesting that fortification of milk with vitamin D would be safe in this
219 respect.

220 A RNI/safe intake of 10μg/d was proposed to ensure that a year-round serum 25(OH)D
221 concentration of ≥25nmol/l is achieved by the 97.5% of the population (SACN 2016). In the
222 current study, a large proportion of those individuals considered to be 'at-risk' (young children
223 aged 1.5-3 y, women of childbearing age (16-49 y), and those aged 65+ y) fell short of the
224 RNI. Although the fortification model was able to successfully increase the proportion of
225 individuals meeting the RNI, the problem was not completely eliminated. This finding
226 emphasises the importance and need for further strategies to increase vitamin D awareness
227 and intake among these groups, particularly in those who may avoid milk/dairy products as
228 part of their habitual diets.

229 Dietary modelling results similar to those reported by the current study have previously
230 been shown by some (Jayaratne et al. 2013; Harika et al. 2016; Ejtahed et al. 2016; Moyersoen
231 et al. 2019) but not others (Allen et al. 2015). In an Iranian population, Ejtahed and colleagues
232 (2016) reported an increase in vitamin D intakes from 2.5μg to 3.3μg/d after simulated
233 fortification of milk, which is in line with that reported in the current study for the same
234 fortification (1μg/100g). Jayaratne et al. (2013) also reported a positive effect of a fortification
235 model, with higher increases in intakes shown (3.6μg to 6.3μg/d), albeit this was achieved by
236 fortifying both milk and breakfast cereals so the bigger effect on daily intake is not
237 unexpected.

238 In contrast, negative effects of a milk fortification model on vitamin D intakes were
239 reported in another recent study using UK population dietary survey data. Allen and

240 colleagues (2015) found that fortification at certain concentrations put a number of
241 participants at risk of exceeding the tolerable UL which is at variance to the current study,
242 even following the highest fortification scenario (2μg/100g). This study, however, used older
243 NDNS results collected in fewer participants than used in the current study, and also failed to
244 justify the considerably higher fortification concentrations chosen. Furthermore, the lower
245 values quoted for the tolerable UL of vitamin D intakes were those of the older European
246 Committee report (European Scientific Committee on Food 2002), as opposed to the more
247 recent guidelines from EFSA (2012).

248 The fortification model used in the current study demonstrated an increased vitamin D
249 intake for the entire population, with whole milk having the largest impact on vitamin D intake
250 as a result of the larger portion size consumed per eating occasion. Despite this larger portion
251 size, as semi-skimmed milk was the most frequently consumed milk in the population overall,
252 its fortification would benefit a greater number of people and therefore have the greatest
253 impact on the vitamin D intake at a population level.

254 The vitamin D_3 concentrations in milk reported in this study are at variance with the results
255 published in some of the latest editions of the McCance and Widdowson (2002; 2014). The
256 7th edition (2014) lists vitamin D for all types of cows' milk as 'trace' with the exception of
257 milk from the Channel Islands which is listed at 0.01μg/100g (McCance & Widdowson 2014).
258 The previous edition listed the average vitamin D content of whole, semi-skimmed and
259 skimmed milk as 0.03μg, 0.01μg and trace per 100g, respectively (Holland et al. 1989;
260 McCance & Widdowson 2002). The increases in vitamin D_3 content of raw and whole milk
261 found in this study, may be as a result of improvements in laboratory methods (Weir et al.
262 2017). Earlier methods of laboratory analysis presented numerous methodological challenges
263 owing to vitamin D's complex structure, often causing complications when extracting the
264 vitamin from the food matrix (Byrdwell et al. 2008) which may also have contributed to the
265 differences in vitamin D_3 content reported. Seasonal variation in vitamin D content in milk
266 across the world has been well documented in the literature (Kurmann & Indyk 1994;
267 Jakobsen & Saxholt 2009) but is not supported by the current study and may be a result of
268 poor weather patterns. In recent years the weather has become more over-cast during the
269 summer months (Sweeney 2016), and this decreases the opportunity for dermal synthesis of
270 vitamin D_3 not only in humans, but also in cattle which synthesise the vitamin in a similar
271 manner (Hymoller & Jensen 2010). Subsequently, the vitamin D status of the cattle influences
272 the vitamin D concentration of the milk produced (Hollis et al. 1981) and therefore, animal
273 husbandry in future should be adapted to ensure a more consistent vitamin D supply

274 throughout the year.

275 Whilst interpreting the current results, a number of limitations should be noted. First is the
276 use of self-reported dietary intakes, as misreporting in the form of under- or over-reporting of
277 certain foodstuffs is a commonplace in participants (Willet 2013). During the NDNS Rolling
278 Programme, the doubly-labelled water technique was used to validate the reported energy
279 intake (Public Health England 2014) and improves confidence in the data. Moreover, the use
280 of dietary data from the largest nationally representative survey in the UK was the most
281 appropriate to test our hypothesis and such data was considerably more reliable than that
282 collected from smaller surveys. Current results are also strengthened by the successful vitamin
283 d fortification programme in Finland (Raulio et al. 2017), and add to the rationale to
284 incorporate fortification in a wide range of food types. Secondly, it was beyond the scope of
285 this project to measure the vitamin D_3 content of all milk types (e.g. semi-skimmed and
286 skimmed), but up-to-date results for the vitamin D_3 content of raw and whole milk from NI
287 have been quantified using a more advanced laboratory technique. Although these values are
288 specific to NI milk, this approach provides novel data on a specific region of the UK, rather
289 than using values from a more widespread and varied pool of data. Owing to the higher
290 vitamin D_3 content of milk reported compared to that in the most recent UK Composition of
291 Foods (McCance & Widdowson 2014), a more widespread update of the vitamin D content
292 of UK milk is warranted. It would also be advantageous to use an alternative analytical
293 technique, such as liquid chromatography mass spectrometry (LC-MS) (Trenerry et al. 2011)
294 in future studies. This more sensitive method would also enable the quantification of the
295 concentrations of other vitamin D metabolites present within milk, e.g. vitamin D_2 and
296 25(OH)D, which contribute to the total vitamin D content (Cashman 2012). Finally, this study
297 has highlighted the potential beneficial effect of fortifying cows' milk with vitamin D on
298 vitamin D intakes across the UK population. Further analysis should determine how this
299 approach would impact the vitamin D contribution from other dairy products (made from the
300 fortified milk), as well as the vitamin D status of the consumer.

301 Conclusion

302 This study suggests that the fortification of UK cows' milk with vitamin D (up to a
303 concentration of 2μg/100g) could be an effective dietary strategy to increase consumer's
304 vitamin D intake, helping more of the UK population to achieve the newly revised RNI for
305 vitamin D of 10μg/d. Importantly, this strategy could translate into a beneficial effect on

306 consumer’s vitamin D status, without putting anyone at risk of exceeding the tolerable UL for
307 the vitamin. Based on the results from this dietary modelling scenario, fortification of all types
308 of milk (whole, semi-skimmed, skimmed and 1% milks) is recommended to maximise the
309 impact to consumers of all ages and make progress towards eradicating vitamin D deficiency
310 among the UK population.

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321 designed the research. R.R.W. and S.S. conducted the research. R.R.W. analysed the data and
322 prepared the manuscript. All authors were involved in interpreting the results, and all read
323 and approved the final manuscript.

324 **Disclosure statement:** The authors declare no conflicts of interest

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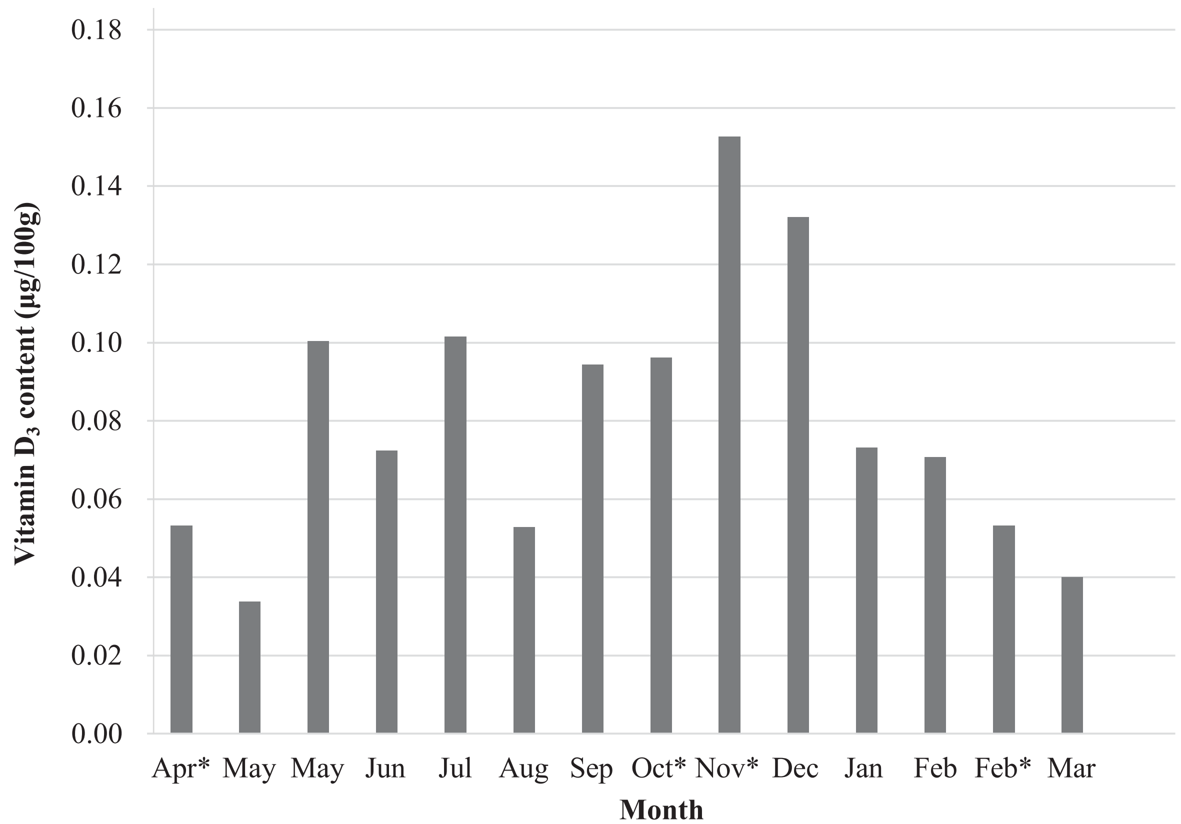

Fig. 1. Vitamin D_3 content (µg/100g) of raw milk produced in Northern Ireland over a year period. Bars show mean vitamin D_3 of samples collected from two processors across Northern Ireland. *Results available from one processor only.

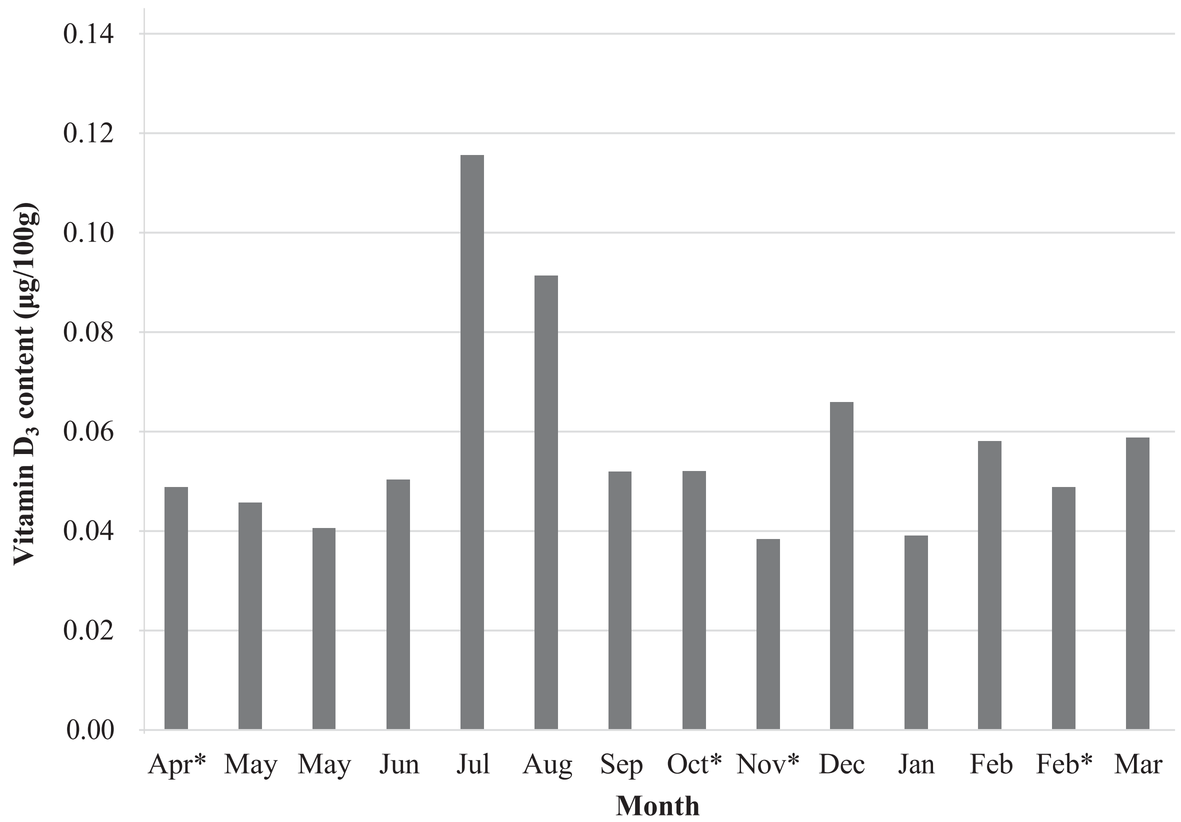

Fig. 2. Vitamin D_3 content (µg/100g) of pasteurised whole milk produced in Northern Ireland over a year period. Bars show mean vitamin D_3 of samples collected from two processors across Northern Ireland. *Results available from one processor only.

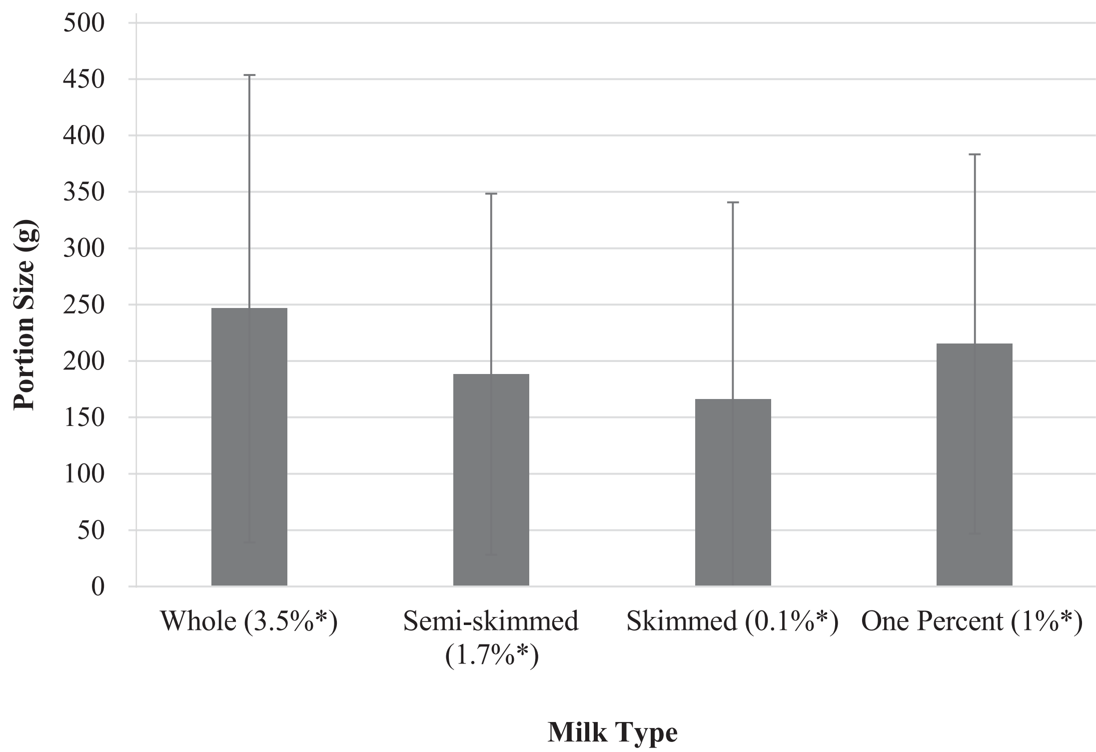

Fig. 3. Mean portion size (g) of milk consumed by participants (*n* 4,156) per eating occasion for each milk type. *Typical fat content of each milk type.

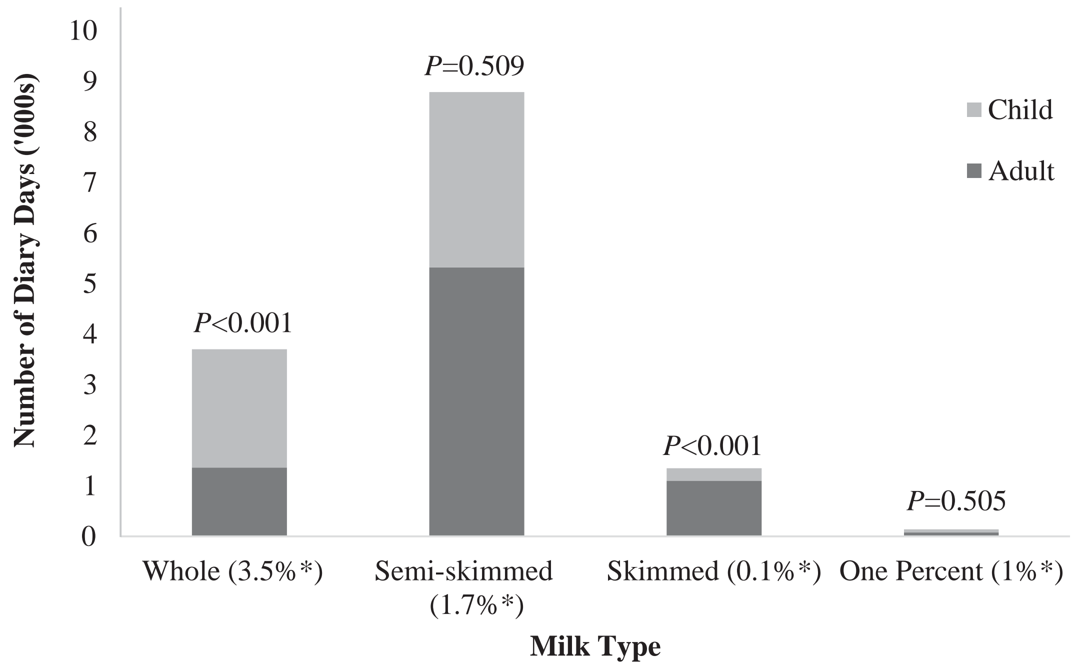

Fig. 4. Frequency of consumption of each milk type by adults (18-94 years; dark bars *n* 2,174) and children (1.5-17 years; light bars, *n* 1,982). *Refers to average fat content of each milk type. *P*-values indicate a significant difference between the number of diary days each type of milk was consumed between adults and children ($P<0.05$).

Table 1: National Diet and Nutrition Survey (NDNS) population data (Public Health England, 2014)

Age (yrs)	Sample size (*n* 4,156)		
	Male	Female	Total
1.5 - 3	207	179	386
4 - 10	414	389	803
11 - 15	278	265	543
16 - 18	167	174	341
19 - 49	471	640	1111
50 - 64	239	305	544
≥ 65	191	237	428
Total	*1967*	*2189*	*4156*

Table prepared using the demographic information provided in the NDNS report (2014)

Table 2: Theoretical impact vitamin D fortification of milk on vitamin D intakes of the population based on the NDNS data (*n* 4,156)

	Total Population					
	Vitamin D intake (μg/day)				Population percentage (%)	
Vitamin D concentration	Mean ± SD	Median	Minimum	Maximum	Meeting RNI[†]	Exceeding UL[‡]
No fortification*	2.50 ± 1.87	2.03	0.00	20.96	0.89	0
1μg/100g	4.20 ± 2.48	3.69	0.02	23.94	2.96	0
1.5μg/100g	5.06 ± 3.08	4.42	0.02	33.98	6.88	0
2μg/100g	5.91 ± 3.77	5.11	0.02	44.01	12.29	0

NDNS, National Diet and Nutrition Survey, dataset available from the UK Data Archives (2014)

[†]RNI, Reference Nutrient Intake (or safe intake) for vitamin D of 10μg/day for those aged >1 year (SACN 2016)

[‡]UL, upper limit of 50μg/day for those ages 1-10 years and 100μg/day for those over 11 years (EFSA 2002)

*Vitamin D content of milk as listed in the McCance and Widdowson (2002)

Table 3: Theoretical impact of vitamin D fortification of milk on vitamin D intakes of those individuals deemed to be at risk of vitamin D deficiency (COMA 1991) based on the NDNS data

	Children aged 1 - 3 years (*n* 386)				Women of childbearing age (*n* 814)				Adults aged over 65 years (*n* 428)			
	Vitamin D intake (μg/day)		Population percentage (%)		Vitamin D intake (μg/day)		Population percentage (%)		Vitamin D intake (μg/day)		Population percentage (%)	
Vitamin D concentration	Mean ± SD	Median	Meeting RNI†	Exceeding UL‡	Mean ± SD	Median	Meeting RNI†	Exceeding UL‡	Mean ± SD	Median	Meeting RNI†	Exceeding UL‡
No fortification*	1.96 ± 2.05	1.41	2.12	0	2.28 ± 1.65	1.82	0.74	0	3.40 ± 2.39	2.75	1.65	0
1μg/100g	4.80 ± 2.59	4.42	4.15	0	3.44 ± 2.03	2.99	1.60	0	5.25 ± 2.79	4.69	6.07	0
1.5μg/100g	6.21 ± 3.42	5.53	12.18	0	4.01 ± 2.39	3.50	2.70	0	6.18 ± 3.20	5.50	13.08	0
2μg/100g	7.63 ± 4.39	6.87	25.65	0	4.59 ± 2.80	3.99	5.04	0	7.10 ± 3.70	6.40	17.76	0

NDNS, National Diet and Nutrition Survey, dataset available from UK Data Archives (2014)

†RNI, Reference Nutrient Intake (or safe intake) for vitamin D of 10μg/day for those over 1 year (SACN 2016)

‡UL, upper limit of 50μg/day for those ages 1-10 years and 100μg/day for those over 11 years (EFSA 2002)

*Vitamin D content of milk as listed in the McCance and Widdowson (2002)

Table 4: Theoretical impact of vitamin D fortification of milk on the dietary vitamin D intake of the population based on reported diary days (*n* 16,539)

	Total vitamin D intake (µg/day)							
	Fortification of milk							
	Not Fortified*		1µg/100g		1.5µg/100g		2µg/100g	
Milk Type	Median	Percentiles	Median	Percentiles	Median	Percentiles	Median	Percentiles
Whole	2.0[a]	1.0-3.6	4.9[b]	3.1-.7.3	6.2[c]	3.9-9.2	7.4[d]	4.5-11.2
Semi-skimmed	2.3[a]	1.2-4.0	4.3[b]	2.9-6.6	5.3[c]	3.5-8.1	6.1[d]	4.0-9.5
Skimmed	2.6[a]	1.2-5.1	4.2[b]	2.4-7.5	5.2[c]	2.9-8.5	6.0[d]	3.1-9.4
One percent	2.7[a]	1.4-8.5	4.6[b]	2.8-9.0	5.5[c]	3.1-9.1	6.5[d]	3.8-9.2

Consumption of milk and baseline vitamin D intake as found in the National Diet and Nutrition Survey, dataset available from UK Data Archives (2014)

* Vitamin D content of milk as listed in the McCance and Widdowson (2002) Percentiles (25th-75th)

[a,b,c,d] Values within a row with different superscript letters are significantly different ($P<0.001$, Friedman Test and Wilcoxon Signed Rank test)