

**ESM Table 1. Major food contributors of gluten and their percentage of contribution at the baseline, mid-point, and most recent FFQs in three cohorts**

<b>NHS</b>		<b>%</b>	<b>NHSII</b>		<b>%</b>	<b>HPFS</b>		<b>%</b>
<b>1986</b>			<b>1991</b>			<b>1986</b>		
Pasta		14.7	Pasta		21.6	Cold cereal		15.0
Whole wheat/oatmeal/whole grain bread		14.5	Mix of frozen & restaurant pizza		14.8	Whole wheat/oatmeal/whole grain bread		14.4
White bread		13.8	Whole wheat/oatmeal/whole grain bread		12.2	Pasta		12.6
Cold cereal		11.6	Bagels/English muffins/rolls		10.4	Mix of frozen & restaurant pizza		9.4
Mix of frozen & restaurant pizza		9.6	Cold cereal		9.0	White bread		9.1
Bagels/English muffins/rolls		9.2	White bread		7.8	Bagels/English muffins/rolls		8.0
Pancakes & waffles		3.6	Pancakes & waffles		4.9	Pancakes & waffles		4.0
Fruit Danish pastry		2.9	Muffins or biscuits		3.4	Regular beer		3.1
Commercial blueberry muffin		2.5	Fruit Danish pastry		2.2	Fruit Danish pastry		3.1
Homemade Danish pastry		2.3	Wheat crackers		1.9	Canned chicken noodle soup		2.5
<b>1998</b>			<b>1999</b>			<b>1998</b>		
Pasta		17.6	Pasta		20.6	Pasta		15.7
Whole wheat/oatmeal/whole grain bread		15.4	Bagels/English muffins/rolls		11.6	Whole wheat/oatmeal/whole grain bread		14.9
Cold cereal		12.7	Whole wheat/oatmeal/whole grain bread		10.6	Cold cereal		13.0
Bagels/English muffins/rolls		10.5	Cold cereal		9.1	Bagels/English muffins/rolls		9.6
White bread		9.1	Mix of frozen & restaurant pizza		8.3	White bread		7.6
Plain, hard, salted pretzels		6.9	White bread		7.5	Mix of frozen & restaurant pizza		5.8
Mix of frozen & restaurant pizza		5.1	Plain, hard, salted pretzels		7.2	Wheat crackers		5.2
Wheat crackers		4.2	Commercially prepared bran muffin		5.0	Plain, hard, salted pretzels		4.6
Commercially prepared bran muffin		4.0	Corn tortillas		3.6	Commercially prepared bran muffin		4.4
Pancakes & waffles		1.5	Wheat crackers		3.3	Corn tortillas		1.9
<b>2010</b>			<b>2011</b>			<b>2010</b>		
Whole wheat/oatmeal/whole grain bread		25.3	Whole wheat/oatmeal/whole grain bread		22.5	Whole wheat/oatmeal/whole grain bread		20.7
Pasta		16.8	Pasta		20.3	Pasta		15.4
Cold cereal		12.3	Cold cereal		10.2	Cold cereal		12.6
White bread		5.1	Mix of frozen & restaurant pizza		6.7	Mix of frozen & restaurant pizza		8.3

Bagels/English muffins/rolls	4.9	Plain, hard, salted pretzels	5.7	Bagels/English muffins/rolls	5.1
Whole wheat crackers	4.7	Bagels/English muffins/rolls	5.6	Whole wheat crackers	4.6
Plain, hard, salted pretzels	4.3	Whole wheat crackers	5.4	White bread	3.5
Rye bread	4.2	White bread	3.2	Plain, hard, salted pretzels	3.4
Mix of regular and low-fat crackers	4.0	Mix of regular and low-fat crackers	2.7	Mix of regular and low-fat crackers	3.3
Mix of frozen & restaurant pizza	3.5	Corn tortillas	2.6	Regular beer	3.2

---

**ESM Table 2. Associations between gluten intake (% energy) and type 2 diabetes risk.**

	Gluten (% energy)					P <sub>trend</sub>
	Q1	Q2	Q3	Q4	Q5	
<i>Nurses' Health Study</i>						
Case/person year	1574/330169	1572/330333	1429/330516	1291/330647	1222/330787	
Model 1 <sup>1</sup>	1	1.01 (0.94, 1.08)	0.92 (0.86, 0.99)	0.83 (0.77, 0.89)	0.79 (0.73, 0.85)	<0.0001
Model 2 <sup>2</sup>	1	0.97 (0.90, 1.04)	0.91 (0.85, 0.98)	0.84 (0.78, 0.90)	0.84 (0.78, 0.91)	<0.0001
Model 3 <sup>3</sup>	1	0.97 (0.90, 1.04)	0.91 (0.84, 0.97)	0.83 (0.77, 0.90)	0.85 (0.79, 0.92)	<0.0001
Model 4 <sup>4</sup>	1	1.00 (0.92, 1.07)	0.95 (0.88, 1.03)	0.89 (0.82, 0.98)	0.92 (0.84, 1.02)	0.03
<i>Nurses' Health Study II</i>						
Case/person year	1678/357080	1166/357757	1004/357885	821/357916	791/357543	
Model 1 <sup>1</sup>	1	0.71 (0.66, 0.77)	0.62 (0.58, 0.67)	0.51 (0.47, 0.56)	0.49 (0.45, 0.54)	<0.0001
Model 2 <sup>2</sup>	1	0.85 (0.79, 0.92)	0.82 (0.76, 0.89)	0.72 (0.66, 0.78)	0.74 (0.68, 0.81)	<0.0001
Model 3 <sup>3</sup>	1	0.86 (0.80, 0.93)	0.84 (0.78, 0.91)	0.74 (0.68, 0.81)	0.77 (0.71, 0.85)	<0.0001
Model 4 <sup>4</sup>	1	0.88 (0.81, 0.96)	0.88 (0.80, 0.96)	0.79 (0.71, 0.88)	0.84 (0.76, 0.94)	<0.0005
<i>Health Professionals Follow-Up Study</i>						
Case/person year	899/159830	731/160226	667/160377	581/160416	521/160259	
Model 1 <sup>1</sup>	1	0.83 (0.75, 0.92)	0.76 (0.69, 0.84)	0.66 (0.59, 0.73)	0.60 (0.53, 0.67)	<0.0001
Model 2 <sup>2</sup>	1	0.87 (0.79, 0.96)	0.84 (0.75, 0.93)	0.77 (0.69, 0.86)	0.77 (0.69, 0.86)	<0.0001
Model 3 <sup>3</sup>	1	0.87 (0.78, 0.96)	0.84 (0.76, 0.93)	0.78 (0.70, 0.87)	0.80 (0.71, 0.89)	<0.0001
Model 4 <sup>4</sup>	1	0.89 (0.80, 0.98)	0.88 (0.78, 0.99)	0.84 (0.74, 0.96)	0.90 (0.78, 1.03)	0.10
<i>Pooled</i>						
Model 1 <sup>1</sup>	1	0.85 (0.81, 0.89)	0.77 (0.73, 0.80)	0.66 (0.63, 0.70)	0.63 (0.60, 0.66)	<0.0001
Model 2 <sup>2</sup>	1	0.90 (0.86, 0.94)	0.85 (0.81, 0.90)	0.77 (0.74, 0.81)	0.78 (0.75, 0.82)	<0.0001
Model 3 <sup>3</sup>	1	0.90 (0.86, 0.94)	0.86 (0.82, 0.90)	0.78 (0.74, 0.82)	0.80 (0.76, 0.85)	<0.0001
Model 4 <sup>4</sup>	1	0.92 (0.88, 0.97)	0.91 (0.86, 0.96)	0.84 (0.79, 0.89)	0.88 (0.83, 0.94)	<0.0001

<sup>1</sup>, estimates are calculated in Cox proportional hazards models. Model 1, adjusted for age;<sup>2</sup>, model 2, further adjusted for ethnicity (White, African American, Asian, and other ethnicity), family history of diabetes (yes/no), smoking status (never, former, current (1–14, 15–24, or ≥25 cigarettes/day), or missing), alcohol intake (gram/day: 0, 0.1–4.9, 5.0–14.9, and >15.0 in women, 0, 0.1–4.9, 5.0–29.9, and >30.0 in men, or missing), physical activity (<3, 3.0–8.9, 9.0–17.9, 18.0–26.9, ≥27.0 MET (metabolic equivalent of task) hours/week, or missing), menopausal status and post-menopausal hormone use (pre-menopause, post-menopause (never, former, or current hormone use), or missing, for women), oral contraceptive use (yes, no, or missing, for Nurses' Health Study II), multivitamin use (yes/no), BMI (<23, 23–24.9, 25–29.9, 30–34.9, >35kg/m<sup>2</sup>, or missing), and total energy intake based on model 1;<sup>3</sup>, model 3, further adjusted for AHEI (in quintiles), folic acid intake (in quintiles), and magnesium intake (in quintiles) based on model 2;<sup>4</sup>, model 4, further adjusted for cereal fibre intake based on model 3.

**ESM Table 3. Spearman correlations of gluten intake with dietary carbohydrate components at the midpoint of follow-up (NHS1998, NHSII 2001, HPFS1998)**

	<b>NHS</b>	<b>NHSII</b>	<b>HPFS</b>
Whole grain	0.38	0.33	0.43
Refined grain	0.65	0.71	0.62
Bran	0.30	0.25	0.32
Germ	0.19	0.17	0.22
Starch	0.71	0.71	0.61
Glycaemic index	0.30	0.25	0.29
Glycaemic load	0.35	0.32	0.41
Cereal fibre	0.61	0.61	0.63

All P values <0.0001.

**ESM Table 4. Associations between and type 2 diabetes adjusting for carbohydrate components.<sup>1</sup>**

<b>Further adjusting for refined grain intake</b>						
NHS	1	0.90 (0.83, 0.97)	0.79 (0.73, 0.86)	0.74 (0.67, 0.81)	0.73 (0.66, 0.81)	<0.001
NHSII	1	0.83 (0.76, 0.91)	0.78 (0.70, 0.86)	0.69 (0.62, 0.77)	0.69 (0.61, 0.78)	<0.001
HPFS	1	0.82 (0.73, 0.91)	0.79 (0.70, 0.89)	0.72 (0.63, 0.82)	0.73 (0.63, 0.84)	<0.001
Pooled	1	0.85 (0.81, 0.90)	0.78 (0.74, 0.83)	0.71 (0.67, 0.76)	0.71 (0.66, 0.76)	<0.001
<b>Further adjusting for whole grain intake</b>						
NHS	1	0.96 (0.89, 1.03)	0.88 (0.81, 0.94)	0.84 (0.78, 0.91)	0.85 (0.79, 0.92)	<0.001
NHSII	1	0.89 (0.82, 0.96)	0.86 (0.79, 0.93)	0.78 (0.72, 0.85)	0.81 (0.74, 0.89)	<0.001
HPFS	1	0.87 (0.78, 0.96)	0.85 (0.76, 0.94)	0.78 (0.70, 0.87)	0.81 (0.72, 0.91)	<0.001
Pooled	1	0.90 (0.86, 0.95)	0.86 (0.82, 0.90)	0.80 (0.76, 0.84)	0.82 (0.78, 0.87)	<0.001
<b>Further adjusting for glycaemic index and glycaemic load</b>						
NHS	1	0.94 (0.87, 1.01)	0.85 (0.79, 0.91)	0.80 (0.74, 0.86)	0.78 (0.72, 0.85)	<0.001
NHSII	1	0.87 (0.80, 0.94)	0.83 (0.77, 0.90)	0.75 (0.69, 0.82)	0.76 (0.69, 0.83)	<0.001
HPFS	1	0.85 (0.77, 0.94)	0.82 (0.74, 0.92)	0.75 (0.67, 0.84)	0.78 (0.69, 0.88)	<0.001
Pooled	1	0.89 (0.85, 0.93)	0.83 (0.79, 0.87)	0.76 (0.72, 0.80)	0.76 (0.72, 0.80)	<0.001
<b>Further adjusting for bran, germ, and starch</b>						
NHS	1	0.90 (0.84, 0.98)	0.80 (0.74, 0.87)	0.75 (0.68, 0.82)	0.74 (0.67, 0.82)	<0.001
NHSII	1	0.86 (0.80, 0.94)	0.82 (0.75, 0.90)	0.73 (0.65, 0.81)	0.72 (0.64, 0.81)	<0.001
HPFS	1	0.85 (0.76, 0.94)	0.82 (0.73, 0.92)	0.75 (0.66, 0.84)	0.78 (0.68, 0.90)	0.0001
Pooled	1	0.87 (0.83, 0.92)	0.81 (0.76, 0.85)	0.73 (0.69, 0.78)	0.74 (0.69, 0.79)	<0.001
<b>Using whole grain adjusted gluten intake as exposure <sup>2</sup></b>						
NHS	1	0.94 (0.87, 1.01)	0.96 (0.88, 1.03)	0.90 (0.83, 0.98)	0.89 (0.82, 0.97)	0.008
NHSII	1	0.84 (0.77, 0.91)	0.85 (0.78, 0.92)	0.78 (0.71, 0.85)	0.81 (0.73, 0.89)	<0.0001
HPFS	1	0.93 (0.84, 1.03)	0.88 (0.79, 0.98)	0.87 (0.77, 0.97)	0.85 (0.75, 0.96)	0.004
Pooled	1	0.89 (0.85, 0.93)	0.89 (0.85, 0.94)	0.84 (0.80, 0.89)	0.84 (0.79, 0.89)	<0.0001
<b>Using refined grain adjusted gluten intake as exposure <sup>2</sup></b>						
NHS	1	1.01 (0.94, 1.09)	0.91 (0.84, 0.98)	0.90 (0.82, 0.98)	0.82 (0.74, 0.92)	<0.0001
NHSII	1	0.87 (0.81, 0.94)	0.82 (0.75, 0.89)	0.83 (0.75, 0.91)	0.82 (0.73, 0.92)	<0.0001
HPFS	1	0.92 (0.83, 1.02)	0.83 (0.74, 0.93)	0.81 (0.71, 0.92)	0.82 (0.71, 0.96)	0.002
Pooled	1	0.94 (0.89, 0.98)	0.86 (0.81, 0.90)	0.85 (0.80, 0.90)	0.82 (0.76, 0.88)	<0.0001

Abbreviations: NHS, Nurses' Health Study; NHSII, Nurses' Health Study; HPFS, the Health Professionals Follow-Up Study.

<sup>1</sup>, model was adjusted for age, ethnicity (White, African American, Asian, and other ethnicity), family history of diabetes (yes/no), smoking status (never, former, current (1–14, 15–24, or ≥25 cigarettes/day), or missing), alcohol intake (gram/day: 0, 0.1–4.9, 5.0–14.9, and >15.0 in women, 0, 0.1–4.9, 5.0–29.9, and >30.0 in men, or missing), physical activity (<3, 3.0–8.9, 9.0–17.9, 18.0–26.9, ≥27.0 MET (metabolic equivalent of task) hours/week, or missing), menopausal status and post-menopausal hormone use (pre-menopause, post-menopause (never, former, or current hormone use), or missing, for women), oral contraceptive use (yes, no, or missing, for Nurses' Health Study II), multivitamin use (yes/no), total energy intake, BMI (<23, 23–24.9, 25–29.9, 30–34.9, >35kg/m<sup>2</sup>, or missing), AHEI (in quintiles), folic acid intake (in quintiles), and magnesium intake (in quintiles).

**ESM Table 5. Stratified analysis of associations between gluten intake and type 2 diabetes risk.<sup>1</sup>**

		Quintiles of saturated fatty acid intake (% energy)					P <sub>trend</sub>	P <sub>interaction</sub>
		Q1	Q2	Q3	Q4	Q5		
Age	<65yrs	1	0.91 (0.86, 0.96)	0.88 (0.83, 0.94)	0.82 (0.77, 0.88)	0.85 (0.78, 0.92)	<0.0001	0.002
	≥65yrs	1	0.94 (0.86, 1.02)	0.90 (0.81, 0.99)	0.87 (0.79, 0.97)	0.93 (0.83, 1.04)	0.06	
BMI	<25kg/m <sup>2</sup>	1	0.86 (0.80, 0.93)	0.84 (0.78, 0.91)	0.79 (0.72, 0.87)	0.80 (0.73, 0.89)	<0.0001	<0.0001
	≥25kg/m <sup>2</sup>	1	0.95 (0.89, 1.01)	0.91 (0.85, 0.98)	0.85 (0.79, 0.92)	0.91 (0.83, 1.00)	0.003	
Physical activity	<18 METs/week	1	0.94 (0.88, 1.00)	0.89 (0.84, 0.95)	0.86 (0.80, 0.93)	0.88 (0.81, 0.96)	0.0002	0.03
	≥18 METs/week	1	0.85 (0.77, 0.93)	0.85 (0.76, 0.94)	0.77 (0.68, 0.86)	0.81 (0.71, 0.92)	0.0004	
Current smoking	No	1	0.92 (0.88, 0.97)	0.88 (0.83, 0.93)	0.83 (0.78, 0.89)	0.87 (0.81, 0.93)	<0.0001	0.83
	Yes	1	0.82 (0.70, 0.97)	0.91 (0.75, 1.09)	0.77 (0.62, 0.96)	0.86 (0.67, 1.10)	0.17	

<sup>1</sup>, model was adjusted for age, ethnicity (White, African American, Asian, and other ethnicity), family history of diabetes (yes/no), smoking status (never, former, current (1–14, 15–24, or ≥25 cigarettes/day), or missing), alcohol intake (gram/day: 0, 0.1–4.9, 5.0–14.9, and >15.0 in women, 0, 0.1–4.9, 5.0–29.9, and >30.0 in men, or missing), physical activity (<3, 3.0–8.9, 9.0–17.9, 18.0–26.9, ≥27.0 MET (metabolic equivalent of task) hours/week, or missing), menopausal status and post-menopausal hormone use (pre-menopause, post-menopause (never, former, or current hormone use), or missing, for women), oral contraceptive use (yes, no, or missing, for Nurses' Health Study II), multivitamin use (yes/no), total energy intake, BMI (<23, 23–24.9, 25–29.9, 30–34.9, >35kg/m<sup>2</sup>, or missing), AHEI (in quintiles), folic acid intake(in quintiles), magnesium intake(in quintiles), and cereal fibre intake (in quintiles).

**ESM Table 6. Sensitivity analysis on associations between gluten intake and diabetes risk.<sup>1</sup>**

<b>Using individual diet components as covariates</b>						
NHS	1	0.98 (0.91, 1.06)	0.92 (0.85, 1.00)	0.90 (0.82, 0.98)	0.94 (0.85, 1.04)	0.08
NHSII	1	0.90 (0.83, 0.98)	0.89 (0.81, 0.98)	0.82 (0.74, 0.91)	0.86 (0.76, 0.96)	0.002
HPFS	1	0.89 (0.80, 0.99)	0.90 (0.80, 1.01)	0.86 (0.75, 0.97)	0.94 (0.81, 1.09)	0.31
Pooled	1	0.93 (0.88, 0.97)	0.90 (0.85, 0.95)	0.86 (0.81, 0.91)	0.90 (0.84, 0.96)	<0.0001
<b>Using baseline gluten intake as exposure</b>						
NHS	1	0.98 (0.91, 1.06)	0.92 (0.86, 1.00)	0.94 (0.87, 1.02)	0.89 (0.82, 0.97)	0.007
NHSII	1	0.91 (0.84, 0.98)	0.94 (0.86, 1.02)	0.91 (0.83, 0.99)	0.89 (0.80, 0.98)	0.03
HPFS	1	0.95 (0.85, 1.05)	0.91 (0.81, 1.01)	0.92 (0.82, 1.03)	0.97 (0.85, 1.10)	0.51
Pooled	1	0.94 (0.90, 0.99)	0.92 (0.87, 0.97)	0.92 (0.87, 0.97)	0.90 (0.85, 0.95)	0.0004
<b>Using baseline BMI as covariate</b>						
NHS	1	0.97 (0.90, 1.05)	0.90 (0.83, 0.97)	0.86 (0.79, 0.94)	0.88 (0.80, 0.97)	0.002
NHSII	1	0.88 (0.81, 0.96)	0.88 (0.80, 0.96)	0.79 (0.71, 0.88)	0.84 (0.75, 0.94)	0.0005
HPFS	1	0.89 (0.80, 0.99)	0.90 (0.80, 1.01)	0.86 (0.75, 0.97)	0.94 (0.81, 1.09)	0.009
Pooled	1	0.91 (0.87, 0.96)	0.87 (0.83, 0.92)	0.81 (0.77, 0.86)	0.85 (0.79, 0.90)	<0.0001

Abbreviations: NHS, Nurses' Health Study; NHSII, Nurses' Health Study; HPFS, the Health Professionals Follow-Up Study.

<sup>1</sup>, model was adjusted for age, ethnicity (White, African American, Asian, and other ethnicity), family history of diabetes (yes/no), smoking status (never, former, current (1–14, 15–24, or ≥25 cigarettes/day), or missing), alcohol intake (gram/day: 0, 0.1–4.9, 5.0–14.9, and >15.0 in women, 0, 0.1–4.9, 5.0–29.9, and >30.0 in men, or missing), physical activity (<3, 3.0–8.9, 9.0–17.9, 18.0–26.9, ≥27.0 MET (metabolic equivalent of task) hours/week, or missing), menopausal status and post-menopausal hormone use (pre-menopause, post-menopause (never, former, or current hormone use), or missing, for women), oral contraceptive use (yes, no, or missing, for Nurses' Health Study II), multivitamin use (yes/no), total energy intake, BMI (<23, 23–24.9, 25–29.9, 30–34.9, >35kg/m<sup>2</sup>, or missing), AHEI (in quintiles, not adjusted when using individual diet components as covariates), folic acid intake (in quintiles), magnesium intake (in quintiles), and cereal fibre intake (in quintiles).

**ESM Table 7. Associations between gluten intake and diabetes risk after excluding participants with CD. <sup>1</sup>**

	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>	<b>Q5</b>	<b>P<sub>trend</sub></b>
NHS	1	0.97 (0.90, 1.04)	0.90 (0.83, 0.97)	0.87 (0.80, 0.95)	0.89 (0.81, 0.99)	0.008
HPFS	1	0.87 (0.79, 0.97)	0.88 (0.78, 0.98)	0.82 (0.72, 0.93)	0.88 (0.76, 1.02)	0.06
Pooled	1	0.94 (0.88, 1.00)	0.89 (0.83, 0.95)	0.85 (0.79, 0.92)	0.89 (0.82, 0.96)	0.0007

Abbreviations: NHS, Nurses' Health Study; HPFS, the Health Professionals Follow-Up Study.

<sup>1</sup>, model was adjusted for age, ethnicity (White, African American, Asian, and other ethnicity), family history of diabetes (yes/no), smoking status (never, former, current (1–14, 15–24, or ≥25 cigarettes/day), or missing), alcohol intake (gram/day: 0, 0.1–4.9, 5.0–14.9, and >15.0 in women, 0, 0.1–4.9, 5.0–29.9, and >30.0 in men, or missing), physical activity (<3, 3.0–8.9, 9.0–17.9, 18.0–26.9, ≥27.0 MET (metabolic equivalent of task) hours/week, or missing), menopausal status and post-menopausal hormone use (pre-menopause, post-menopause (never, former, or current hormone use), or missing, for women), oral contraceptive use (yes, no, or missing, for Nurses' Health Study II), multivitamin use (yes/no), total energy intake, BMI (<23, 23–24.9, 25–29.9, 30–34.9, >35kg/m<sup>2</sup>, or missing), AHEI (in quintiles, not adjusted when using individual diet components as covariates), folic acid intake (in quintiles), magnesium intake (in quintiles), and cereal fibre intake (in quintiles).