

**Supplemental Table 1.** Morphine equivalency classification\*

<b>Weaker than morphine</b>	<b>Equivalent to morphine</b>	<b>Stronger than morphine</b>
acetaminophen; butalbital; caffeine; codeine	acetaminophen; caffeine; chlorpheniramine; hydrocodone; phenylephrine	acetaminophen; oxycodone
acetaminophen; caffeine; dihydrocodeine	acetaminophen; hydrocodone	aspirin; oxycodone
acetaminophen; codeine	aspirin; hydrocodone	fentanyl
acetaminophen; pentazocine	belladonna; opium	hydromorphone
acetaminophen; propoxyphene	chlorpheniramine; hydrocodone	oxycodone
acetaminophen; tramadol	chlorpheniramine; hydrocodone; phenylephrine	oxymorphone
anhydrous calcium iodide; codeine	chlorpheniramine; hydrocodone; pseudoephedrine	
aspirin; butalbital; caffeine; codeine	diphenhydramine; hydrocodone; phenylephrine	
chlorpheniramine; codeine; pseudoephedrine	guaifenesin; hydrocodone	
codeine	guaifenesin; hydrocodone; pseudoephedrine	
codeine; guaifenesin	homatropine; hydrocodone	
codeine; guaifenesin; pseudoephedrine	hydrocodone	
codeine; phenylephrine; promethazine	hydrocodone; ibuprofen	
codeine; promethazine	hydrocodone; phenylephrine; pyrilamine	
meperidine	hydrocodone; phenylpropanolamine	
naloxone; pentazocine	hydrocodone; pseudoephedrine; triprolidine	
pentazocine	morphine	
propoxyphene	tapentadol	
tramadol		

\* Opioids were classified into three strength categories (weaker/equivalent/stronger than morphine) based on morphine equivalency criteria established by the Centers for Disease Control and Prevention (Frenk SM, Porter KS, Paulozzi LJ. Prescription Opioid Analgesic Use Among Adults : United States, 1999-2012. NCHS Data Brief. 2015;Feb.(189):1–8). Opioids often used in treatment for opioid dependence or withdrawal (methadone, buprenorphine, and buprenorphine; naloxone) were excluded from our outcome variable. Naloxone; pentazocine was retained due to the combination with pentazocine.

**Supplemental Table 2.** Typology of reasons for prescription opioid use

<b>ICD-10 CM Code*</b>	<b>ICD-10 CM Code Description</b>
<b>Back Pain</b>	
M54	Dorsalgia
M54.5	Low back pain
M54.9	Dorsalgia, unspecified
<b>Injury Pain</b>	
S97.8	Crushing injury of foot
T14.9	Unspecified injury
<b>Joint Pain</b>	
M06.9	Rheumatoid arthritis, unspecified
M13	Other arthritis
M19.9	Osteoarthritis, unspecified site
M1A	Chronic gout
M25.5	Pain in joint
M25.51	Pain in shoulder
M25.55	Pain in hip
M25.56	Pain in knee
M79.606	Pain in leg, unspecified
M79.673	Pain in unspecified foot
M94.26	Chondromalacia, knee
<b>Muscle/Nerve Pain</b>	
G50	Disorders of trigeminal nerve
M62.83	Muscle spasm
M79.1	Myalgia
M79.2	Neuralgia and neuritis, unspecified
M79.7	Fibromyalgia
<b>Neck Pain</b>	
M54.2	Cervicalgia
<b>Other/Unspecified Pain</b>	
B02	Zoster [herpes zoster]
E07.9	Disorder of thyroid, unspecified
G40	Epilepsy and recurrent seizures
G43	Migraine
G47.0	Insomnia
G89	Pain, not elsewhere classified
G89.18	Other acute postprocedural pain
G89.3	Neoplasm related pain (acute) (chronic)
G89.4	Chronic pain syndrome
H66.9	Otitis media, unspecified
H92.0	Otalgia
J00	Acute nasopharyngitis [common cold]
J02	Acute pharyngitis
J03	Acute tonsillitis
J09	Influenza due to certain identified influenza viruses

K04.7	Periapical abscess without sinus
K08.4	Partial loss of teeth
K08.8	Other specified disorders of teeth and supporting structures
K46	Unspecified abdominal hernia
K57	Diverticular disease of intestine
K87	Disorders of gallbladder, biliary tract and pancreas in diseases classified elsewhere
K92.9	Disease of digestive system, unspecified
L93	Lupus erythematosus
N20.0	Calculus of kidney
N30	Cystitis
N42.9	Disorder of prostate, unspecified
N94	Pain and other conditions associated with female genital organs and menstrual cycle
R05	Cough
R06.9	Unspecified abnormalities of breathing
R07.9	Chest pain, unspecified
R09.3	Abnormal sputum
R10	Abdominal and pelvic pain
R10.9	Unspecified abdominal pain
R51	Headache
R52	Pain, unspecified
Z48.8	Encounter for other specified postprocedural aftercare
Z96.65	Presence of artificial knee joint

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NHANES, National Health And Nutrition Examination Survey

\* Reasons for opioid use were coded using International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM). For purposes of the present study, we adapted a previously developed typology (Mundkur ML, Rough K, Huybrechts KF, Levin R, Gagne JJ, Desai RJ, Paterno E, Choudhry NK, Bateman BT. Patterns of opioid initiation at first visits for pain in United States primary care settings. *Pharmacoepidemiol Drug Saf* 2018;27:495–503) to categorize the ICD-10-CM codes into six major types of pain: back pain, injury pain, joint pain, muscle/nerve pain, neck pain, and other.

**Supplemental Table 3.** Primary and secondary opioid outcomes by BMI category, NHANES 2003-2016 (n=25,424)

	n (%) <sup>*</sup>					
	<b>Underweight</b> <b>(15-19.9 kg/m<sup>2</sup>)</b>	<b>Normal</b> <b>(20-24.9 kg/m<sup>2</sup>)</b>	<b>Overweight</b> <b>(25-29.9 kg/m<sup>2</sup>)</b>	<b>Obese I</b> <b>(30-34.9 kg/m<sup>2</sup>)</b>	<b>Obese II</b> <b>(35-39.9 kg/m<sup>2</sup>)</b>	<b>Obese III</b> <b>(40-80 kg/m<sup>2</sup>)</b>
<b>Primary Outcome</b>						
No opioid use	769 (92.8%)	5186 (94.1%)	8192 (93.8%)	5360 (92.7%)	2366 (90.3%)	1689 (87.3%)
Prescription opioid use	68 (7.2%)	331 (5.9%)	521 (6.2%)	418 (7.3%)	269 (9.7%)	255 (12.7%)
<b>Secondary Outcome:</b>						
<b>Duration of opioid use</b>						
No opioid use	769 (92.8%)	5186 (94.1%)	8192 (93.8%)	5360 (92.7%)	2366 (90.3%)	1689 (87.3%)
< 90 days of opioid use	22 (2.4%)	103 (1.9%)	146 (1.7%)	101 (1.9%)	66 (2.4%)	48 (2.2%)
≥ 90 days of opioid use	46 (4.8%)	228 (4.0%)	375 (4.5%)	317 (5.3%)	203 (7.3%)	207 (10.5%)
<b>Secondary Outcome:</b>						
<b>Strength of opioid use<sup>†</sup></b>						
No opioid use	769 (92.8%)	5186 (94.1%)	8192 (93.8%)	5360 (92.7%)	2366 (90.3%)	1689 (87.3%)
Weaker than morphine	13 (0.9%)	103 (1.8%)	157 (1.9%)	143 (2.1%)	91 (3.1%)	77 (3.8%)
Equivalent/Stronger than morphine	55 (6.2%)	228 (4.3%)	364 (5.2%)	275 (6.6%)	178 (6.6%)	178 (8.9%)

NHANES, National Health And Nutrition Examination Survey; BMI, Body Mass Index

<sup>\*</sup> Proportions sample weighted based on NHANES analytic guidelines.

<sup>†</sup> Opioids were classified into three strength categories (weaker/equivalent/stronger than morphine) based on morphine equivalency criteria established by the Centers for Disease Control and Prevention (Frenk SM, Porter KS, Paulozzi LJ. Prescription Opioid Analgesic Use Among Adults : United States, 1999-2012. NCHS Data Brief. 2015;Feb.(189):1–8). Equivalent to morphine and stronger than morphine were grouped for this analysis.

**Supplemental Table 4.** Multinomial logistic regression: Association between BMI and prescription opioid strength\* among adults ages 35-79, NHANES 2003-201 (n=25,424)

	Weaker than Morphine			Equivalent to or Stronger than Morphine		
	RRR†	95% CI	P-value	RRR†	95% CI	P-value
<b>BMI, kg/m<sup>2</sup></b>						
Underweight (15-19.9)	0.49	0.25-0.98	0.045	1.29	0.87-1.90	0.20
Normal (20-24.9)	1.00 (Ref)	-	-	1.00 (Ref)	-	-
Overweight (25-29.9)	1.07	0.76-1.52	0.70	1.12	0.85-1.48	0.42
Obese I (30-34.9)	1.14	0.80-1.63	0.48	1.31	0.99-1.74	0.06
Obese II (35-39.9)	1.59	1.09-2.31	0.02	1.73	1.32-2.27	<0.001
Obese III (40-80)	2.10	1.39-3.17	0.001	2.44	1.76-3.38	<0.001

NHANES, National Health And Nutrition Examination Survey; BMI, Body Mass Index; RRR, Relative Risk Ratio; CI, Confidence Interval

\*Opioids were classified into three strength categories (weaker/equivalent/stronger than morphine) based on morphine equivalency criteria established by the Centers for Disease Control and Prevention (Frenk SM, Porter KS, Paulozzi LJ. Prescription Opioid Analgesic Use Among Adults : United States, 1999-2012. NCHS Data Brief. 2015;Feb.(189):1-8).

† Sample weighted based on NHANES analytic guidelines and adjusted for age (35-44 years, 45-54 years, 55-64 years, 65-79 years), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other), education (less than high school, high school or equivalent, high school, some college, college or higher), insurance status (uninsured, insured), smoking status (never, former, current) and survey year (2003, 2005, 2007, 2009, 2011, 2013, 2015). No opioid use was used as the base outcome for the multinomial logistic regression.

‡ The association between BMI and prescription opioid use was consistently observed across categories of opioid strength (p-value for Wald test comparing the BMI coefficients across strength levels, 0.69).

**Supplemental Table 5.** Multivariable logistic regression: Association between obesity and prescription opioid use among adults ages 35-79, NHANES 2003-2016 (n=25,424)

	OR	95% CI	P-value
BMI, kg/m <sup>2</sup>			
Non-obese (20-29.9)	1.00 (Ref)	-	-
Obese (≥ 30)	1.45	1.27-1.66	<0.001
Age, years			
35-44	1.00 (Ref)	-	-
45-54	1.22	1.01-1.48	0.043
55-64	1.47	1.22-1.76	<0.001
65-79	1.30	1.06-1.59	0.01
Sex			
Female	1.00 (Ref)	-	-
Male	0.74	0.66-0.83	<0.001
Race/ Ethnicity			
Non-Hispanic White	1.00 (Ref)	-	-
Non-Hispanic Black	0.77	0.65-0.92	0.003
Hispanic	0.66	0.53-0.81	<0.001
Non-Hispanic Other	0.85	0.64-1.13	0.26
Education			
Less than high school	1.00 (Ref)	-	-
High school or equivalent	0.86	0.72-1.03	0.11
Some college	0.84	0.73-0.98	0.02
College or higher	0.41	0.32-0.52	<0.001
Insurance status			
Uninsured	1.00 (Ref)	-	-
Insured	1.83	1.47-2.28	<0.001
Smoking Status			
Never	1.00 (Ref)	-	-
Former	1.49	1.27-1.75	<0.001
Current	2.50	2.15-2.90	<0.001
Survey Year			
2003	1.00 (Ref)	-	-
2005	0.94	0.69-1.28	0.70
2007	1.04	0.76-1.43	0.82
2009	0.99	0.76-1.29	0.94
2011	1.14	0.84-1.55	0.39
2013	1.16	0.84-1.61	0.37
2015	0.98	0.75-1.28	0.89

NHANES, National Health And Nutrition Examination Survey; BMI, Body Mass Index; OR, Odds Ratio; CI, Confidence Interval

\* Sample weighted based on NHANES analytic guidelines and adjusted for age (35-44 years, 45-54 years, 55-64 years, 65-79 years), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other), education (less than high school, high school or equivalent, high school, some college, college or higher), insurance status (uninsured, insured), smoking status (never, former, current) and survey year (2003, 2005, 2007, 2009, 2011, 2013, 2015).

**Supplemental Table 6.** Prevalence\* of prescription opioid use attributable to various reasons for use by obesity status among adults ages 35-79, NHANES 2013-2016 (n=7,596)

Self-reported reasons for opioid use†	Prevalence of self-reported reason for opioid use in overall population, % (95% CI)	Prevalence of self-reported reason for opioid use in adults with obesity, % (95% CI)	Prevalence of self-reported reason for opioid use in adults without obesity, % (95% CI)	Prevalence difference, obese vs. non-obese (95% CI)	P-value for difference ‡	Contribution to differences, % §
Any Reason	7.4% (6.1, 8.6)	9.3% (7.7, 11.0)	5.9% (4.6, 7.2)	3.4% (2.0, 4.9)	<0.001	-
Back Pain	3.3% (2.5, 4.0)	4.3% (3.1, 5.4)	2.5% (1.9, 3.2)	1.8% (0.8, 2.8)	0.001	53%
Joint Pain	1.9% (1.4, 2.3)	2.6% (1.8, 3.5)	1.3% (0.9, 1.7)	1.3% (0.3, 2.3)	0.009	38%
Muscle/Nerve Pain	1.3% (0.9, 1.8)	2.0% (1.3, 2.8)	0.8% (0.4, 1.2)	1.2% (0.4, 2.0)	0.004	35%
Injury Pain	0.9% (0.6, 1.2)	1.0% (0.6, 1.5)	0.8% (0.5, 1.1)	0.3% (-0.2, 0.8)	0.26	9%
Other Pain	1.3% (0.9, 1.6)	1.4% (0.8, 1.9)	1.2% (0.7, 1.7)	0.2% (-0.7, 1.0)	0.69	6%
Neck Pain	0.3% (0.1, 0.4)	0.2% (0.0, 0.4)	0.3% (0.0, 0.6)	-0.1% (-0.5, 0.2)	0.50	-3%

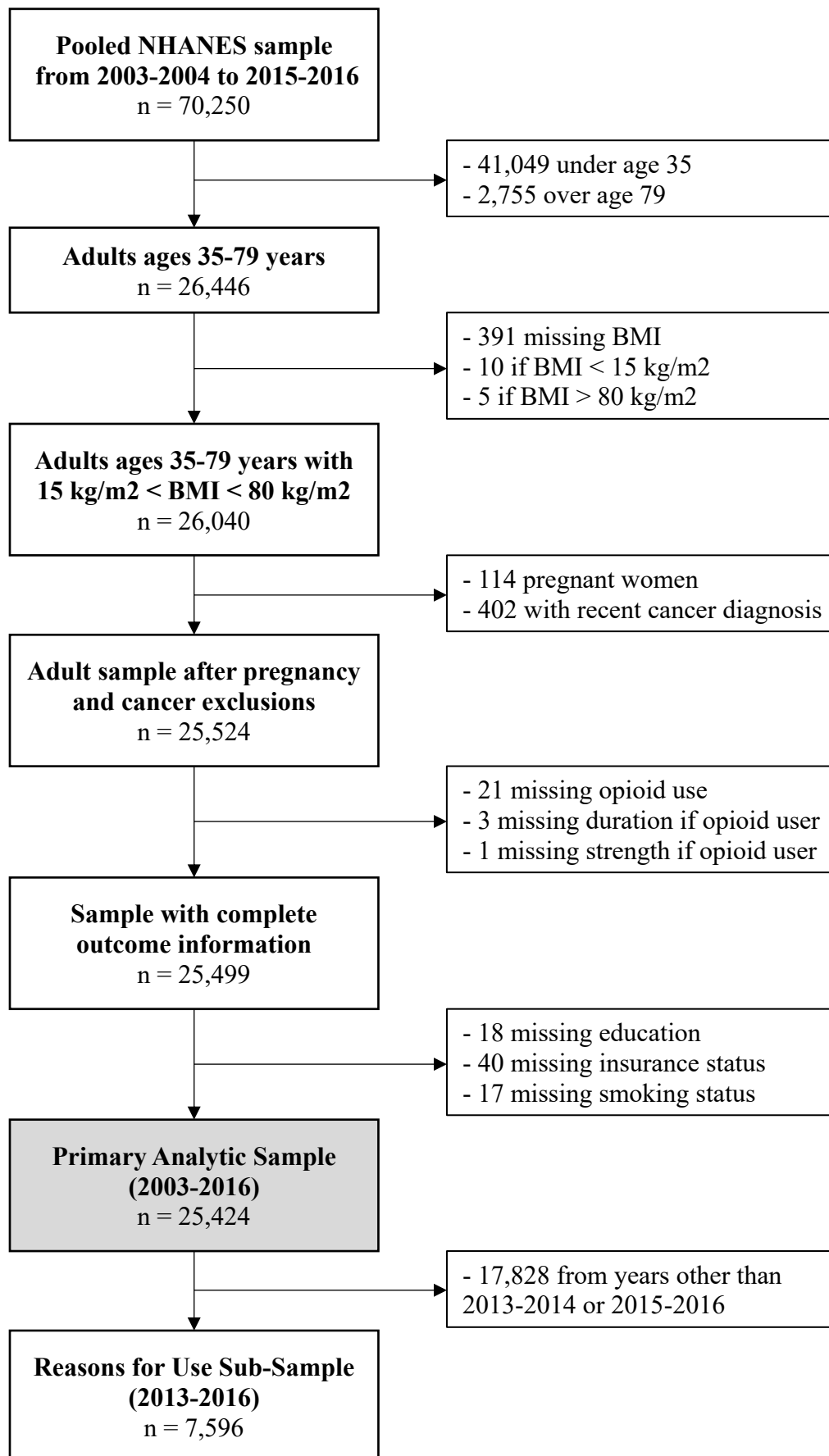
\* All prevalence values are age-adjusted.

† Prescription opioid use can be ascribed to multiple reasons. See Table 2, Supplemental Digital Content 1 for ICD-10-CM codes included in each pain category.

‡ P-values for the difference were calculated post-estimation using Wald tests.

§ Contribution to differences is the difference in each reason-specific opioid use prevalence divided by the difference between obese and non-obese in prevalence of opioid use for any reason. Since respondents could report more than one reason for each prescription opioid, the total percent contributions to differences for all pain reasons exceeds 100%. Sample Interpretation: *Back pain alone or in combination with additional pain indications contributed to 51% of excess opioid use in obese individuals compared to individuals with non-obese BMI.*

**Supplemental Figure 1.** Sample inclusion/exclusion criteria



**Supplemental Figure 2.** Prescription opioid strength by BMI, NHANES 2003-2016 (n=25,424)

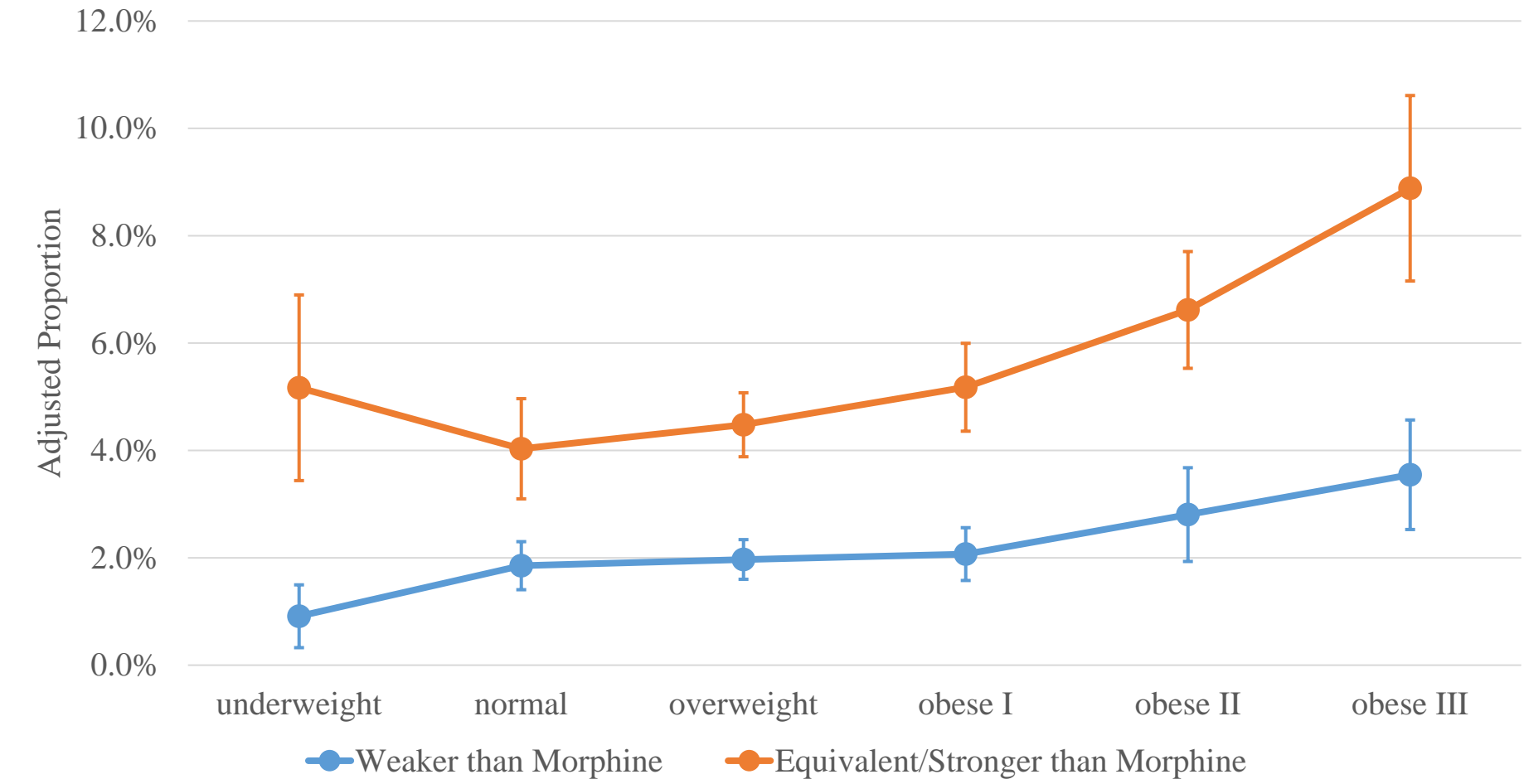


Figure 2 (Supplemental Digital Content 1) shows the proportion of reporting use of a prescription opioid weaker than morphine and use of an opioid equivalent to/stronger than morphine by BMI category in the sample of US adults ages 35-79 years. Estimates were generated using the margins command in Stat following a multinomial logistic regression of strength of opioid use (see Table 4, Supplemental Digital Content 1). Estimates were sample weighted according to NHANES analytic guidelines and adjusted for age (35-44 years, 45-54 years, 55-64 years, 65-79 years), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other), education (less than high school, high school or equivalent, high school, some college, college or higher), insurance status (uninsured, insured), smoking status (never, former, current) and survey year (2003, 2005, 2007, 2009, 2011, 2013, 2015). Error bars show the 95% confidence intervals for the estimates.