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Does the Housing Unit's Type and Size Affect Health?

Yuval Arbel (Corresponding author)

Sir Harry Solomon School of Economics and Management

Western Galilee College, Acre 2412101, Israel

E-mail: YuvalAr@wgalil.ac.il

Chaim Fialkoff

Institute of Urban and Regional Studies, Hebrew University of Jerusalem

Mt. Scopus, Jerusalem, 9190501, Israel

E-mail: cfialk@gmail.com

Amichai Kerner

School of Real Estate, Netanya Academic College, Netanya 4223587, Israel

E-mail: kerneram@netvision.net.il

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Abstract

Recent medical studies have examined ways to offer more spatial planning opportunities to increase a person's level of physical activity. These studies demonstrate a decreasing prevalence of obesity in denser and less car-oriented communities with mixed land uses. Yet, apart from these environmental effects, the impact of characteristics of the housing unit itself (e.g., type and size), combined with socio-demographic variables (e.g., the number of children, marital status, place of birth, country of origin, and gender) on the body mass index (BMI) has not been examined previously. Based on a two-year longitudinal survey of the Israeli Central Bureau of Statistics (CBS), the current study examines this potential implication based on the BMI measure. Stratification by gender indicates opposite effects of suburbanization on projected BMI of women and men, who move from smaller condominiums in multi-family buildings to single family units and to larger apartments.

Keywords: Suburbanization, Body Mass Index, Obesity

1. Introduction

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (WHO Report, 2017). The lack of physical activity and obesity have been identified by the World Health Organization as a global pandemic and the fourth leading risk factor for global mortality responsible for an estimated 3.2-5.0 million deaths annually (Sallis et. al., 2016; WHO report, 2017). To cope with this trend, the World Health Organization recommends regular moderate intensity physical activity – such as walking, cycling, or participating in sports – as an important mean to reduce the risk of cardiovascular diseases, diabetes, colon and breast cancer, depression, a hip or vertebral fracture and help control weight. (WHO report, 2017).

A related but not readily apparent aspect of the problem of obesity and lack of physical exercise is associated with urban economics and spatial planning. The typical suburbanization process in the 60s and 70s of the 20th century has been characterized by urban sprawl, and the predominance of car-oriented communities (Note 1). These processes, which are particularly prominent in US cities (e.g., Nivola, 1998; O'Sullivan, 2012: 181-184), have been followed by a sharp increase in health problems related to prevalence of obesity rates (e.g., Zhao and Kaestner, 2010; Griffin et. al., 2013)(Note 2). Referring to 1999-2004, Ogden *et. al.* (2006) estimated that 66.3% of the US adults are overweight or obese and 17.1% of the US children and adolescents are overweight. Yet, until the beginning of the new millennium, and in spite of the long standing tradition of walking as a form of physical activity, public health aspects of these suburbanization trends have rarely been considered in the medical literature (see Saelens and Handy, 2008 for a review).

Recent medical studies examined ways to offer more spatial planning opportunities to increase physical activities. Sallis *et. al.* (2016) studied the impact of six spatial planning characteristics in 14 cities worldwide on physical activity measures. Those were based on accelerometers that participants wore around the waist seven days a week in waking hours during the experiment period. Findings suggest that of the six measures, four (net residential density, intersection density, public transport density, and number of parks) are positively and significantly correlated with measures of physical activity.

Creatore *et. al.* (2016) investigated the relationship between neighborhood walkability ranking and overweight, obesity and diabetes in Ontario, Canada. Their findings suggest a significant change in the prevalence of obesity and diabetes at neighborhoods with walkability rankings.

Yet, to the best of our knowledge, apart from these spatial planning effects, the impact of characteristics of the dwelling unit itself (e.g., type and size), combined with socio-demographic variables (e.g., the number of children, marital status, place of birth, origin, and gender) on the body mass index (BMI) has not been previously examined (Note 3). Thus, the objective of the current study is twofold: (1) to demonstrate that in addition to other spatial planning factors, dwelling unit characteristics play an important role in determining walkability and BMI levels. (2) to show the different impact of the dwelling unit design factor across gender.

Based on a two-year *longitudinal* survey of the Israeli Central Bureau of Statistics (CBS), which became available recently, the current study examines these potential implications on the BMI measure among adult females and males. Stratification by gender is a conventional approach in both the medical and econometric literature on cause of overweight and obesity. Indeed, numerous studies reported on both physiological and psychological differences between females and males. The former group of physiological studies include: Atalayer *et. al.* (2014), who investigated sexually dimorphic functional connectivity in response to high vs. low energy-dense food cues in obese humans; Furnman *et. al.* (2014), who provide explanations for the more robust immune responses of females compared with males; and Goedecke *et. al.* (2016), who examined sex differences in insulin sensitivity and insulin response with increasing age in black South African men and women (Note 4). The latter group of psychological studies explored the relationship between body weight and academic performance, focusing on gender differences (e.g., Sabia and Reese, 2015; Barone, and Nese, 2016).

The outcomes of our study indicate opposite effects of suburbanization on the BMI of women and men moving from smaller, multi-family condominiums to single family units and larger apartments. While projected BMI of females is expected to ***drop*** significantly with the movement from condominiums to single family units (by 1.30%-1.46%) and with additional rooms (by 0.13% ×ROOM_SQ), projected BMI of males is expected to ***rise*** significantly with the movement from condominiums to single family units (by 1.04%-1.16%) and with additional rooms (by 0.65%). These findings are at odds with previous medical findings regarding women, and may be explained on the grounds of traditional division of labor by gender (Note 5). Moreover, many medical studies documented differences in the physiological responses of females and males under equal conditions (e.g., Renehan *et. al.*, 2008; Hatch *et. al.*, 2010).

Additional findings suggest a significant 11.69%-3.59% drop in the projected BMI among both female and male originating from Asian and African countries with relocation from condominiums to single family homes. Once again, these findings might be at odds with previous medical findings referring to r communities with higher population densities and mixed land uses. One possible interpretation is that single family homes provide more rural-like environment to people who immigrated from Asian and African countries.

Finally, the projected BMI of a male living in a single family home drops significantly with an increasing number of children and at a decreasing rate. A possible interpretation is that fathers with larger single housing units tend to be more active and play with their children. In contrast, the projected BMI of a female living in a 3.5 rooms apartment (the sample mean) rises significantly with more children at a decreasing rate.

Research findings suggest that as long as obesity is considered to be a serious pandemic, city planners should account for the impact of dwelling unit characteristics as-well-as other spatial planning factors on walkability and BMI levels. Also, and given the opposite effects of housing type and size on gender, we suggest a simple criterion to make an optimal choice of apartment for married couples by aggregating the BMI of both gender for each number of rooms. An appropriate simulation suggests that if the minimum aggregated BMI is a criterion of housing choice, for a 20-year old married couple or older without children, the optimal BMI is obtained for a single family home and an apartment with one room.

The remainder of this study is organized as follows. Section 2 reports the descriptive statistics. Section 3 describes the methodology and results. Finally, Section 4 concludes and summarizes.

2. Descriptive Statistics

Table 1 displays the descriptive statistics of the pooled sample, which includes 8,957 observations covering up to two years (2015-2016) and 2,673 households, where the age brackets of female (male) members were restricted to 21-62 (21-67) years old. The lower age-limit is designed to capture adults after 2-3 years of compulsory military service. The upper age-limit is based on the retirement age for the workforce - 62 for women and 67 for men. In addition, the average value of the variable Y2016, which equals 1 for 2016 and 0 for 2015 is 0.48. The null hypothesis according to which Y2016 equals 0.49 is not rejected statistically (calculated *t*-value with 8,956 degrees of freedom of –1.2459). This outcome indicates that the sample is close to become strongly balanced (Note 6).

Table 1. Descriptive Statistics

VARIABLES	Description	Obs.	Mean	STD	Min	Max
INDWEIGHT	Weight in kilograms	8,957	74.35	15.46	44	120
HEIGHT	Height in meters	8,957	1.70	0.09	1.49	1.9
BMI	$Body\ Mass = \frac{WEIGHT}{HEIGHT^2}$	8,957	25.59	4.49	14.04	48.68
CONDOMINIUM	1=conventional multifamily house in a condominium; 0=otherwise	8,957	0.58	0.49	0	1
PENTHOUSE_DUPLEX	1=penthouse and duplex; 0=otherwise	8,957	0.07	0.25	0	1
GARDEN	1=Garden; 0=otherwise	8,957	0.05	0.21	0	1
SINGLE_FAMILY	1=single-family unit; 0=otherwise	8,957	0.31	0.46	0	1
Y2016	1=2016; 0=2015	8,957	0.48	0.50	0	1
ROOMS	Number of rooms	8,791	3.78	1.05	1	5
BALCONY	1=balcony; 0=otherwise	8,957	0.40	0.49	0	1
AGE	Age in years	8,957	41.95	12.77	21	67
SINGLE	1=single; 0=otherwise	8,957	0.21	0.41	0	1
MARRIED	1=married; 0=otherwise	8,957	0.69	0.46	0	1
DIVORCED	1=divorced; 0=otherwise	8,957	0.08	0.28	0	1
WIDOWED	1=widow; 0=otherwise	8,957	0.02	0.13	0	1
JEWISH	1=Jewish; 0=otherwise	8,957	0.73	0.45	0	1
ARAB	1=Arab; 0=otherwise	8,957	0.24	0.42	0	1
OTHER	1=Other; 0=otherwise	8,957	0.03	0.19	0	1
NATIVE_ISRAELIS	1=native Israeli; 0=otherwise	8,957	0.76	0.43	0	1
IMM_EUROPE_AMERICA	1=immigrant Europe-America; 0=otherwise	8,957	0.19	0.39	0	1
IMM_ASIA_AFRICA	1=immigrant Asia-Africa; 0=otherwise	8,957	0.05	0.21	0	1

VARIABLES	Description	Obs.	Mean	STD	Min	Max
DOMSHELP	1=has domestic help; 0=otherwise	8,954	0.11	0.32	0	1
HHSIZE	Number of persons in the household	8,957	3.96	1.99	1	27
HAS_CHILDREN	1=has at least one child below 17; 0=otherwise	8,957	0.57	0.50	0	1
BELOW_17	Ratio between number of households member below 17 and the total number of household members in percentage points for households with at least one child	5,078	46.06	15.93	12.50	83.33

Notes: The sample includes 8,957 observations×years covering up to two years (2015-2016), and 2,673 households, where the age of female (male) members was restricted to 21-62 (21-67) years old. This restriction is based on the retirement age for the workforce, which is 62 years old for women and 67 years old for men.

The average BMI in the pooled sample is 25.59 and the standard deviation is 4.49 (BMI). Both the respective 95% and 99% confidence intervals ((25.50, 25.68) and (25.47, 25.71)) imply rejection of the null hypothesis that the average body fat equals 25 percent. Consequently, the sample mean is slightly above body fat of 25 percent, a widely adopted definition of overweight. When stratified by gender, the mean BMI of 24.82 (26.31) for female (male) respondents is significantly lower (higher) than the 25 percent benchmark at the 5% and 1% significance levels (Note 7). Finally, the 1.49 BMI difference across gender is statistically significant at the 1% significance level (*t*-value with 8,492.13 degrees of freedom of 15.82).

Figure 1 displays deciles of BMI stratified by gender in our sample. The BMI is calculated as $\frac{WEIGHT}{HEIGHT^2}$ where WEIGHT is measured in kilograms and HEIGHT is measured in meters. According to Au and Johnston, 2015: "BMI (kg/m^2) is a measure of weight-for-height used to proxy body fat percentage" (page 1405). The vertical (horizontal) axis in Figure 1 measures the BMI (the decile and mean BMI).

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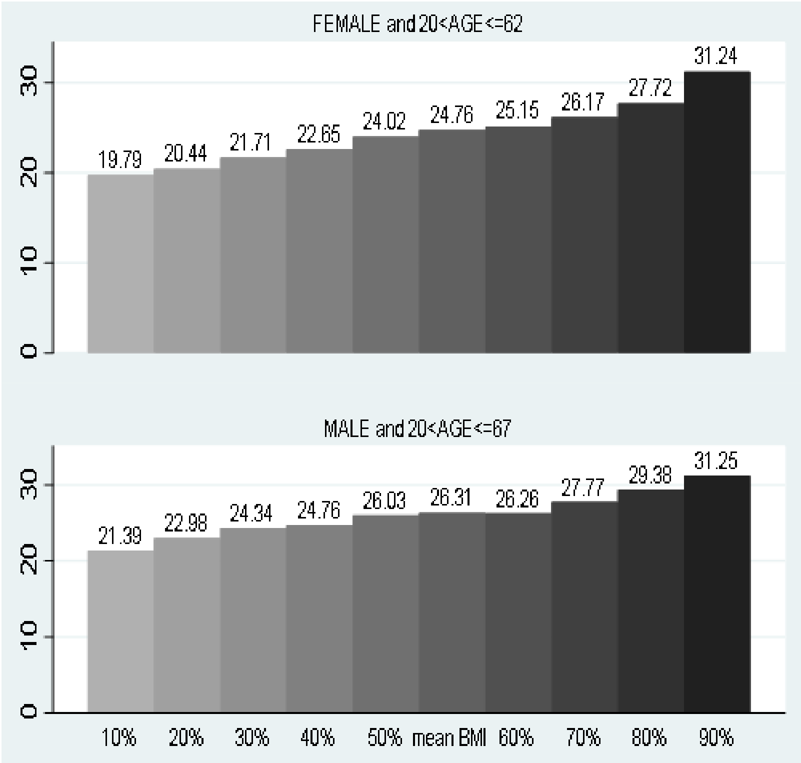

Figure 1. Deciles of Body Mass Index (BMI) Stratified by Gender

Notes: The figure displays the distribution of the BMI by deciles stratified by gender and based on a longitudinal survey of the Israeli Central Bureau of Statistics, which covers two years (2015 and 2016). The sample is representative and restricted to female (male) respondents whose age is 21-62 (21-67) years old. The upper limit of age is the retirement age for female and male, respectively. The BMI is calculated as $\frac{WEIGHT}{HEIGHT^2}$ where WEIGHT is measured in kilograms and HEIGHT is measured in meters. The vertical (horizontal) axis measures the BMI (the decile and mean BMI). A widely adopted definition of overweight is a BMI greater than or equal to 25, with obesity defined as BMI ≥ 30 (Qin and Pan, 2016; page 1293). For 12.79% (15.87%) of the female (male) participants, BMI ≥ 30.

A widely adopted definition of overweight is a BMI greater than or equal to 25, with obesity defined as BMI ≥ 30 (Qin and Pan, 2016; page 1293; OECD, 2016; page 98) (Note 8). For 12.79% (15.87%) of the female (male) participants in our representative sample of the Israeli population, BMI ≥ 30. These frequencies are similar to those in the Netherlands – 13%; and France and Luxemburg – 15%-16%, where the OECD average is 16%. In eight OECD countries, namely, United Kingdom, Estonia, Turkey, Hungary, Latvia, Iceland, Ireland and Malta, BMI ≥ 30 for at least 20% of the population. (OECD, 2016: 4.13 Self-Reported Obesity among Adults above 15 years, 2014 (or latest year); page 99).

Returning to Table 1, two main groups of explanatory variables are housing characteristics and socio-demographic variables. The housing characteristics include structure type and number of rooms. 58% of the housing units are conventional multifamily units in condominiums (CONDOMINIUMS); 7% are penthouse and duplexes (PENTHOUSE_DUPLEX); 5% are garden apartments (GARDEN) and 31% are single-family units (SINGLE_FAMILY). The average apartment includes a significant number of rooms above 3.50 (the calculated *t*-value with 8,790 degrees of freedom is 24.79), where the distribution stretches from a minimum of one room to a maximum of five rooms (ROOMS) (Note 9). Finally, 40% of the units have at least one balcony (BALCONY).

Referring the socio-demographic variables, the average age in years is 41.95 (AGE), where the minimum age is 20 and the maximum age is 67 (the retirement age for men). In terms of household type, of the 8,957 observations×years, 21% are single (SINGLE), 69% are married (MARRIED), 8% are divorced (DIVORCED) and 2% are widowed (WIDOW). Regarding ethnicity characteristics, of the 8,957 observations×years, 73% are Jewish (JEWISH), 24% are Arabs (ARAB), and 3% are other (OTHER). Concerning country of origin, of the 8,957 observations×years, 76% are native Israelis (NATIVE_ISRAELIS), 19% are immigrants from European or American countries (IMM_EUROPE_AMERICA), and 5% are immigrants from Asian or African countries (IMM_ASIA_AFRICA).And finally, considering outside for housework, 11% of the observations×years use professional domestic help for housekeeping (DOMSHELP).

Additional socio-demographic variables include household size and the number of children. The average household size is about 4 persons (HHSIZE) and the null hypothesis of 4 persons is supported at the 1% significance level (99% confidence interval of (3.90, 4.01). Of the 8,957 observations × years, 57% have at least one child below 17 years (HAS_CHILDREN). For the group of 5,078 observations×years with at least one child below 17 years, the average ratio between the number of household members below 17 and the total number of household members is 46.06% (BELOW_17). The modal of this variable is 50%, implying a frequency of 1,093 observations×years with family size of 4 persons and for whom BELOW_17=50%. Consequently, the typical number of children below 17 per household is two.

3. Methodology and Results

3.1 The Empirical Model

Consider the following basic structural model:

$$\ln(BMI) = i \cdot \alpha_0 + HOUSING\_CHARACT \cdot \alpha + SOCIO\_DEMOGRAPHIC \cdot \beta + u_1 \quad (1)$$

Where ln(*BMI*) is the natural logarithm of the BMI measure, *i* is a column vector of ones and α_0 is the constant term; $HOUSING\_CHARACT$ is a matrix of four housing characteristics (*PENTHOUSE_DUPLEX*; *GARDEN*; *SINGLE_FAMILY;* where the base category is *CONDOMINIUMS*; and *BALCONY*), *SOCIO_DEMOGRAPHIC* is a matrix of eleven socio demographic variables (*AGE; MARRIED; DIVORCED; WIDOW;* where the base category is *SINGLE*; *ARAB*; *OTHER*; where the base category is *JEWISH*; *IMM_EUROPE_AMERICA; IMM_ASIA_AFRICA;* where the base category is *NATIVE_ISRAELIS*; *DOMSHELP*; *HHSIZE*; *BELOW_17*); α, β are column vectors of parameters ($\alpha^T = [\alpha_1, \alpha_2, \alpha_3, \alpha_4]$ and $\beta^T = [\alpha_5, \alpha_6, \cdots, \alpha_{13}, \alpha_{15}]$ where α^T, β^T are the transpose of the column vectors α, β) and u_1 is a column vector of stochastic random disturbance terms.

Partition of the matrices to column vectors of variables yields the following model with 15 explanatory variables:

$$\ln(BMI) = \alpha_0 + \alpha_1 PENTHOUSE\_DUPLEX + \alpha_2 GARDEN + \alpha_3 SINGLE\_FAMILY + \alpha_4 BALCONY + \alpha_5 AGE + \alpha_6 MARRIED + \alpha_7 DIVORCED + \alpha_8 WIDOW + \alpha_9 ARAB + \alpha_{10} OTHER + \alpha_{11} IMM\_EUROPE\_AMERICA + \alpha_{12} IMM\_ASIA\_AFRICA + \alpha_{13} DOMSHELP + \alpha_{14} HHSIZE + \alpha_{15} BELOW\_17 + u_1 \quad (1a)$$

One potential extension of the basic model is the supplement of interaction terms, which permits variation of the parameters with the type of dwelling. To apply this extension, the following restrictions should be imposed on the parameters:

$$(0)-(3)\ \ \alpha_j = \beta_j \ \text{ for } \ j = 0,1,2,3$$

$$(4)-(15)\ \ \alpha_j = \beta_{2j-4} + \beta_{2j-3} \times SINGLE\_FAMILY \ \text{ for } \ j = 4,5,6,\cdots,12,13,14,15.$$

Substitution of these restrictions yields the following extended model with 27 explanatory variables:

$$\ln(BMI) = \beta_0 + \beta_1 PENTHOUSE\_DUPLEX + \beta_2 GARDEN + \beta_3 SINGLE\_FAMILY + \beta_4 BALCONY + \beta_5 BALCONY \times SINGLE\_FAMILY + \beta_6 AGE + \beta_7 AGE \times SINGLE\_FAMILY + \beta_8 MARRIED + \beta_9 MARRIED \times SINGLE\_FAMILY + \beta_{10} DIVORCED + \beta_{11} DIVORCED \times SINGLE\_FAMILY + \beta_{12} WIDOW + \beta_{13} WIDOW \times SINGLE\_FAMILY + \beta_{14} ARAB + \beta_{15} ARAB \times SINGLE\_FAMILY + \beta_{16} OTHER + \beta_{17} OTHER \times SINGLE\_FAMILY + \beta_{18} IMM\_EUROPE\_AMERICA + \beta_{19} IMM\_EUROPE\_AMERICA \times SINGLE\_FAMILY + \beta_{20} IMM\_ASIA\_AFRICA + \beta_{21} IMM\_ASIA\_AFRICA \times SINGLE\_FAMILY + \beta_{22} DOMSHELP + \beta_{23} DOMSHELP \times SINGLE\_FAMILY + \beta_{24} HHSIZE + \beta_{25} HHSIZE \times SINGLE\_FAMILY + \beta_{26} BELOW\_17 + \beta_{27} BELOW\_17 \times SINGLE\_FAMILY + u_2 \quad (1b)$$

A similar empirical model is obtained in the case that the housing characteristics matrix contains *ROOMS* and *ROOMS_SQ* (the number of rooms raised to the second power) as two additional explanatory variables reflecting the size of the unit (Note 10). This variation of the empirical model yields:

$$\ln(BMI) = \gamma_0 + \gamma_1 PENTHOUSE\_DUPLEX + \gamma_2 GARDEN + \gamma_3 SINGLE\_FAMILY + \gamma_4 ROOMS + \gamma_5 ROOMS\_SQ + \gamma_6 BALCONY + \gamma_7 AGE + \gamma_8 MARRIED + \gamma_9 DIVORCED + \gamma_{10} WIDOW + \gamma_{11} ARAB + \gamma_{12} OTHER + \gamma_{13} IMM\_EUROPE\_AMERICA + \gamma_{14} IMM\_ASIA\_AFRICA + \gamma_{15} DOMSHELP + \gamma_{16} HHSIZE + \gamma_{17} BELOW\_17 + u_3 \quad (2a)$$

Following this variation, the interaction term will be with ROOMS. To apply this extension, the following restrictions should be imposed on the parameters:

$$(0)-(5)\ \ \gamma_j = \delta_j \ \text{ for } \ j = 0,1,2,3,4,5$$

$$(6)-(17)\ \ \gamma_j = \delta_{2j-6} + \delta_{2j-5} \times ROOMS \ \text{ for } \ j = 6,7,8,\cdots,14,15,16,17.$$

Substitution of these restrictions yields the following extended model with 29 explanatory variables:

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$$\ln(BMI) = \delta_0 + \delta_1 PENTHOUSE\_DUPLEX + \delta_2 GARDEN + \delta_3\, SINGLE\_FAMILY + \delta_4\, ROOMS + \delta_5\, ROOMS\_SQ + \delta_6\, BALCONY + \delta_7\, BALCONY \times ROOMS + \delta_8\, AGE + \delta_9\, AGE \times ROOMS + \delta_{10}\, MARRIED + \delta_{11}\, MARRIED \times ROOMS + \delta_{12}\, DIVORCED + \delta_{13}\, DIVORCED \times ROOMS + \delta_{14}\, WIDOW + \delta_{15}\, WIDOW \times ROOMS + \delta_{16}\, ARAB + \delta_{17}\, ARAB \times ROOMS + \delta_{18}\, OTHER + \delta_{19}\, OTHER \times ROOMS + \delta_{20}\, IMM\_EUROPE\_AMERICA + \delta_{21}\, IMM\_EUROPE\_AMERICA \times ROOMS + \delta_{22}\, IMM\_ASIA\_AFRICA + \delta_{23}\, IMM\_ASIA\_AFRICA \times ROOMS + \delta_{24}\, DOMSHELP + \delta_{25} DOMSHELP \times ROOMS + \delta_{26}\, HHSIZE + \delta_{27}\, HHSIZE \times ROOMS + \delta_{28}\, BELOW\_17 + \delta_{29}\, BELOW\_17 \times ROOMS + u_4 \quad (2b)$$

Based on the conventional practice in the medical literature, we estimate equations (1a), (1b), (2a), (2b) separately for females and males. Many studies demonstrate different relations among some cancer types, obesity and gender; (see Renehan *et. al.*, 2008 for a meta-analysis) and compared with males, latter development of hypertension and only after menopause among women (Yoshida et. al., 2011). As the subsequent analysis demonstrates in our study, this practice is justified on the grounds that the pooled sample yields insignificant coefficients of *SINGLE_FAMILY* and *ROOMS* when the basic models without interaction terms are applied.

3.2 Estimation Results obtained from Equations (1a)-(1b)

Table 2 displays the results obtained from the estimation of equations (1a)-(1b). Columns (1)-(4) present the results for females, and columns (5)-(8) exhibit the outcomes for males. The odd (even) columns are the full (step-wise) models. The latter model gradually omits variables with insignificant coefficients. Columns (1)-(2) and (5)-(6) (Columns (3)-(4) and (7)-(8) includes (excludes) the interaction variables with SINGLE_FAMILY. The Variance Inflating Factor (VIF) measures the level of collinearity, where VIF above 10 indicates a high degree of collinearity. Robust standard errors are given in parentheses. * significant at the 10% significance level. ** significant at the 5% significance level. *** significant at the 1% significance level.

Table 2. Regression Analysis Stratified by Type of Dwelling Unit and Gender of the Resident

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
Constant	2.9218***	2.9285***	2.9351***	2.9340***	3.1162***	3.1128***	3.1132***	3.1148***
	(0.0140)	(0.0116)	(0.0120)	(0.0117)	(0.0110)	(0.0075)	(0.0094)	(0.0074)
PENTHOUSE_DUPLEX	-0.0134	–	-0.0149	–	0.0090	–	0.0088	–
	(0.0105)	–	(0.0105)	–	(0.0096)	–	(0.0096)	–
GARDEN	-0.0037	–	-0.0048	–	0.0013	–	0.0001	–
	(0.0114)	–	(0.0113)	–	(0.0100)	–	(0.0099)	–
SINGLE_FAMILY	0.0275	–	-0.0146**	-0.0130**	-0.0022	–	0.0114**	0.0106**
	(0.0267)	–	(0.0060)	(0.0057)	(0.0212)	–	(0.0048)	(0.0046)
BALCONY	-0.0030	–	-0.0030	–	0.0044	–	0.0041	–
	(0.0054)	–	(0.0053)	–	(0.0044)	–	(0.0044)	–
BALCONY×SINGLE_FAMILY	-0.0030	–	-0.0030	–	0.0044	–	0.0041	–

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
	(0.0054)	–	(0.0053)	–	(0.0044)	–	(0.0044)	–
AGE	0.0053***	0.0051***	0.0051***	0.0051***	0.0022***	0.0024***	0.0022***	0.0023***
	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
AGE×SINGLE_FAMILY	-0.0009*	–	–	–	-0.0002	–	–	–
	(0.0005)	–	–	–	(0.0004)	–	–	–
MARRIED	0.0221**	0.0189***	0.0223***	0.0182***	0.0518***	0.0443***	0.0528***	0.0433***
	(0.0093)	(0.0062)	(0.0083)	(0.0062)	(0.0078)	(0.0050)	(0.0070)	(0.0048)
MARRIED×SINGLE_FAMILY	0.0037	–	–	–	0.0048	–	–	–
	(0.0144)	–	–	–	(0.0126)	–	–	–
DIVORCED	0.0079	–	0.0104	–	0.0145	–	0.0140	–
	(0.0117)	–	(0.0117)	–	(0.0095)	–	(0.0096)	–
WIDOWED	0.0638***	0.0477**	0.0535***	0.0485**	0.0237	–	0.0353	–
	(0.0227)	(0.0192)	(0.0203)	(0.0192)	(0.0443)	–	(0.0300)	–
WIDOW×SINGLE_FAMILY	-0.0550	–	–	–	0.0377	–	–	–
	(0.0456)	–	–	–	(0.0528)	–	–	–
ARAB	0.0897***	0.0858***	0.0832***	0.0845***	0.0287***	0.0293***	0.0265***	0.0304***
	(0.0081)	(0.0064)	(0.0068)	(0.0064)	(0.0072)	(0.0054)	(0.0060)	(0.0054)
ARAB×SINGLE_FAMILY	-0.0186	–	–	–	-0.0052	–	–	–
	(0.0151)	–	–	–	(0.0127)	–	–	–
OTHER	0.0030	–	0.0018	–	0.0036	–	-0.0011	–
	(0.0154)	–	(0.0143)	–	(0.0168)	–	(0.0156)	–
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
OTHER×SINGL E_FAMILY	-0.0567	–	–	–	-0.0291	–	–	–
	(0.0395)	–	–	–	(0.0432)	–	–	–
IMM_EUROPE_AMERICA	0.0413***	0.0442***	0.0335***	0.0365***	0.0122	0.0177***	0.0162**	0.0187***
	(0.0085)	(0.0075)	(0.0074)	(0.0069)	(0.0077)	(0.0060)	(0.0065)	(0.0060)
EUROPE×SING LE_FAMILY	-0.0258	-0.0385**	–	–	0.0168	–	–	–
	(0.0176)	(0.0151)	–	–	(0.0144)	–	–	–
IMM_ASIA_AFRICA	0.0073		-0.0198	–	-0.0098	–	-0.0182*	–
	(0.0159)		(0.0147)	–	(0.0114)	–	(0.0096)	–
ASIA×SINGLE_FAMILY	-0.1147***	-0.1169***	–	–	-0.0223	-0.0359**	–	–
	(0.0359)	(0.0308)	–	–	(0.0207)	(0.0164)	–	–
DOMSHELP	-0.0061	–	-0.0034	–	-0.0123	–	-0.0072	–
	(0.0120)	–	(0.0085)	–	(0.0085)	–	(0.0064)	–
DOMSHELP×S INGLE_FAMILY	0.0055	–	–	–	0.0088	–	–	–
	(0.0169)	–	–	–	(0.0128)	–	–	–
HHSIZE	0.0021	0.0032**	0.0033*	0.0032**	-0.0001	–	0.0017	–
	(0.0020)	(0.0015)	(0.0018)	(0.0016)	(0.0016)	–	(0.0014)	–
HHSIZE×SINGLE_FAMILY	0.0036	–	–	–	0.0068**	0.5462×10^{-2}***	–	–
	(0.0043)	–	–	–	(0.0031)	(0.0016)	–	–
BELOW_17	0.0001	–	0.0000	–	-0.0001	–	-0.0002*	–
	(0.0002)	–	(0.0001)	–	(0.0001)	–	(0.0001)	–
BELOW_17×SINGLE_FAMILY	-0.0003	–	–	–	-0.0003	-0.0368×10^{-2}**	–	–
	(0.0003)	–	–	–	(0.0002)	(0.0002)	–	–

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
Gender	FEMALE	FEMALE	FEMALE	FEMALE	MALE	MALE	MALE	MALE
Interaction with single-family	YES	YES	NO	NO	YES	YES	NO	NO
Observations	4,318	4,318	4,318	4,318	4,636	4,636	4,636	4,636
VIF	4.04	1.16	1.37	1.15	4.02	1.62	1.40	1.12
R-squared	0.161	0.1585	0.1559	0.1548	0.0932	0.0911	0.0914	0.0892
F-statistic	34.39	105.6	54.66	116.2	20.17	68.91	32.49	94.54

Notes: The Variance Inflating Factor (VIF) measures the level of collinearity, where VIF above 10 indicates high degree of collinearity. Robust standard errors are given in parentheses. * significant at the 10% significance level. ** significant at the 5% significance level. *** significant at the 1% significance level.

Results indicate opposite effects of suburbanization on the BMI of women and men moving from multi-family condominium units to single family dwelling units. While projected BMI of females is expected to drop significantly with the movement from condominiums to single family units (by 1.30%-1.46%), projected BMI of males is expected to rise significantly with the movement from condominiums to single family units (by 1.04%-1.16%). Recent empirical studies (e.g., Sallis *et. al.*, 2016; Creatore et. al., 2016) demonstrate a negative relationship between suburbanization and the level of physical activities including walkability. The findings in our study regarding women may thus differ with previous medical findings. Yet, they provide justification to the model that includes interaction terms with single family units.

Figure 2 simulates the effect of variation of the dwelling unit type from condominium to single family unit on the projected level of BMI of 20-year-old or older married female and male. Projections were obtained from columns (4) and (8) in Table 2. Each projected value was transformed from ln(BMI) to BMI by the exponential function. The upper figure describes the aggregated projected BMI of both genders with the unit's type. The middle (lower) figure describes projected BMI of 20-year-old female (male) with the unit's type. The 20-year-old married male is expected to be overweight whether he lives in condominium or not (99% confidence interval for condominium of $24.30 \leq proj(BMI) \leq 25.01$ where $proj(BMI) \geq 25$ is defined as overweight. Consequently, the optimal choice regarding BMI would be a single-family unit.

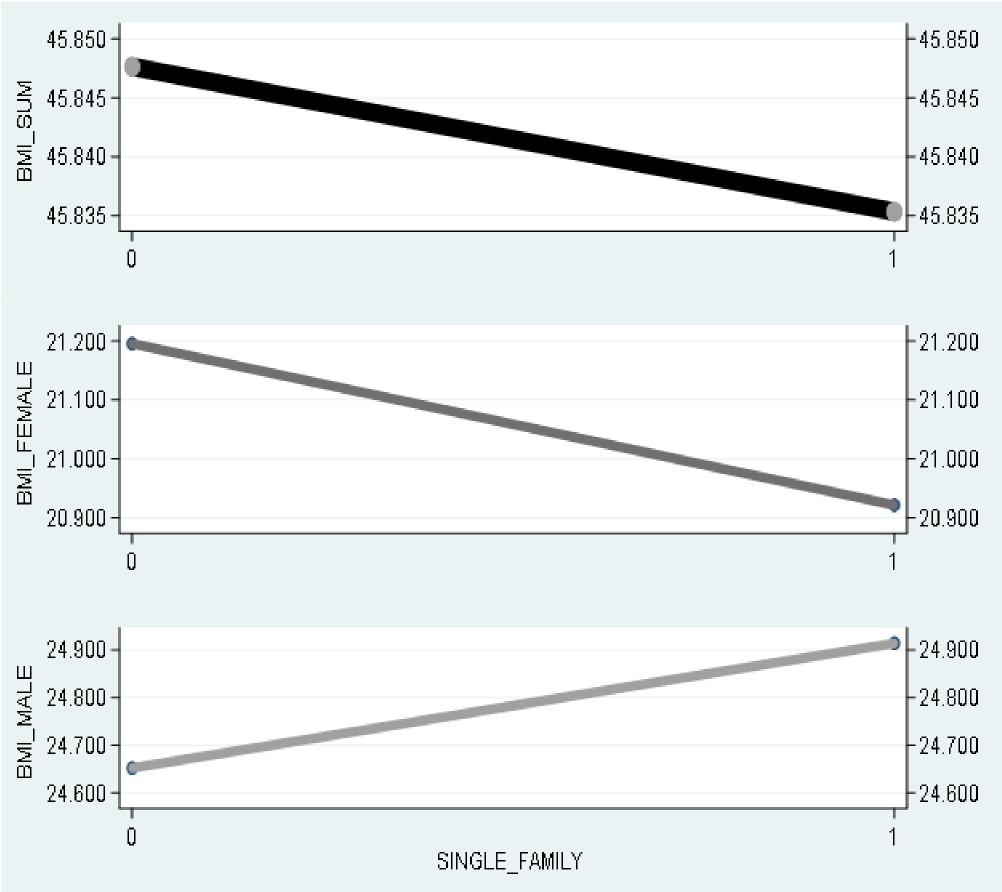

Figure 2. Variation of Females and Males BMI with the Structure Type

Notes: The figure simulates the effect of variation of the structure type from multi-family condominium to single family unit on the projected level of BMI of 20-year-old married men and women. Projections were obtained from columns (4) and (8) in Table 2. Each projected value was transformed from ln(BMI) to BMI by the exponential function. The upper figure describes the aggregated projected BMI of both gender with the unit's type. The middle (lower) figure describes projected BMI of 20-year-old female (male) with the unit's type. The 20-year-old married male is expected to be overweight whether he lives in condominium or not (99% confidence interval for condominium of $24.30 \leq proj(BMI) \leq 25.01$ where $proj(BMI) \geq 25$ is defined as overweight. Consequently, the optimal choice would be a single-family unit.

Additional findings from Table 2 suggest that, as expected, projected BMI rises significantly by 0.22%-0.53% with each addition year-of-age, and by 1.82%-5.28% with a shift from single to married status for both genders. Compared with single females, projected BMI of a widow is expected to increase by 4.77%-6.38%. Compared with their Jewish counterparts, projected BMI of Arabs is higher significantly by 2.65%-8.97% for both genders. Compared with native Israelis, projected BMI of immigrants from European or American countries is higher significantly by 1.62%-4.42% for both genders. All the coefficients are statistically significant at the 5%-1% significance level.

Three interesting outcomes have been obtained from the interaction terms with single-family units. Compared with other female groups, projected BMI of female immigrants from

European-American origin, who reside in single family homes is lower significantly by 3.85% (significant at the 5% significance level). Compared with other female and male groups, projected BMI of immigrants from Asian-African origin who live in single family homes is lower significantly by 11.47%-11.69% for females (at the 1% significance level) and by 3.59% for males (at the 5% significance level). Finally, each additional family member is expected to raise significantly the projected BMI of the male household member living in a single family unit by 0.5462% (at the 1% significance level). In contrast, a one percent increase in the BELOW_17 variable is expected to drop significantly the projected BMI of the male household member living in a single family unit by 0.0368% (significant at the 5% significance level).

Figure 3 simulates the outcomes obtained from the latter coefficients. The simulation refers to married men living in a single-family home with an increasing number of children. For each additional child, on the one hand, projected BMI is expected to rise significantly by 0.54621%. On the other hand, the component of drop in the projected BMI with the total number of children is given by the formula $-.03684\% \times 100 \times (C/(C+2))$ where C is the number of children. The figure demonstrates a total decrease in the projected BMI from 0.66951% (the first child) to 2.40099% (the eight child), where the drop occurs at a decreasing paste for each additional child.

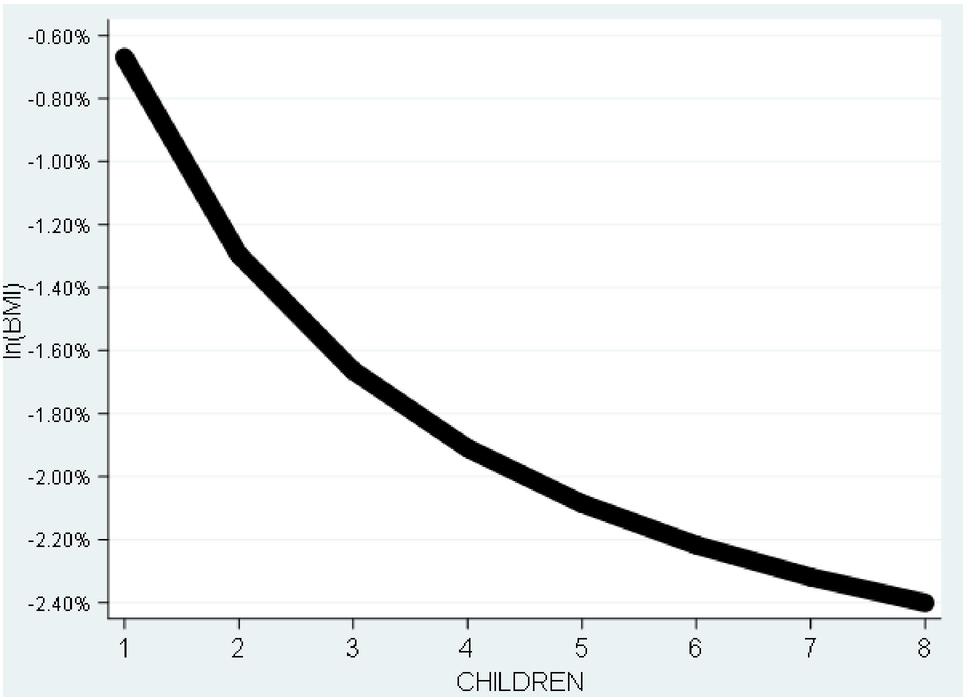

Figure 3. Variation of Males BMI in Single-Family Homes with the Number of Children

Notes: The simulation is based on column (6) in Table 2. The objective is to demonstrate the BMI drop of males living in single-family units with each additional child. Data for the figure is given in the Table 3.

Table 3.

CHILDREN (C)	(1)=coef of HHSIZE	(2)=−.03684% × 100 × ($C/(C+2)$)	(3)=(1)+(2)
1	0.54621%	–1.21572%	–0.66951%
2	0.54621%	–1.8420%	–1.29579%
3	0.54621%	–2.2104%	–1.66419%
4	0.54621%	–2.45667%	–1.91046%
5	0.54621%	–2.63214%	–2.08593%
6	0.54621%	–2.76375%	–2.21754%
7	0.54621%	–2.86533%	–2.31912%
8	0.54621%	–2.9472%	–2.40099%

(3c) Estimation Results Obtained from Equations (2a)-(2b)

Table 4 displays the results obtained from the estimation of equations (2a)-(2b). Columns (1)-(4) present the results for females, and columns (5)-(8) exhibit the outcomes for males. The odd (even) columns are the full (step-wise) models. The latter model gradually omits variables with insignificant coefficients. Columns (1)-(2) and (5)-(6) (Columns (3)-(4) and (7)-(8)) includes (excludes) the interaction variables with ROOMS. The Variance Inflating Factor (VIF) measures the level of collinearity, where VIF above 10 indicates high degree of collinearity. Robust standard errors are given in parentheses. * significant at the 10% significance level. ** significant at the 5% significance level. *** significant at the 1% significance level.

Table 4. Regression Analysis Stratified by Number of Rooms and Gender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
Constant	2.9225***	2.9276***	2.9396***	2.9412***	3.1287***	3.1453***	3.0964***	3.0958***
	(0.0465)	(0.0116)	(0.0287)	(0.0122)	(0.0360)	(0.0079)	(0.0231)	(0.0107)
PENTHOUSE_DUPLEX	-0.0117	–	-0.0109	–	0.0045	–	0.0049	–
	(0.0108)	–	(0.0108)	–	(0.0097)	–	(0.0096)	–
GARDEN	-0.0019	–	-0.0029	–	-0.0028	–	-0.0024	–
	(0.0116)	–	(0.0115)	–	(0.0102)	–	(0.0101)	–
SINGLE_FAMILY	-0.0096	–	-0.0082	–	0.0067	–	0.0077	–
	(0.0065)	–	(0.0065)	–	(0.0052)	–	(0.0052)	–
BALCONY	0.0010	–	0.0009	–	0.0017	–	0.0016	–
	(0.0055)	–	(0.0055)	–	(0.0045)	–	(0.0044)	–
ROOMS	0.0056	–	0.0010	–	0.0031	–	0.0077	0.0065***
	(0.0189)	–	(0.0158)	–	(0.0150)	–	(0.0128)	(0.0022)
ROOMS_SQ	-0.0014	–	-0.0012	-0.0013***	-0.0013	-0.0016***	-0.0002	–
	(0.0024)	–	(0.0022)	(0.0004)	(0.0020)	(0.0005)	(0.0018)	–
AGE	0.0056***	0.0051***	0.0051***	0.0052***	0.0004	–	0.0021***	0.0023***
	(0.0009)	(0.0002)	(0.0003)	(0.0002)	(0.0007)	–	(0.0002)	(0.0002)
AGE×ROOMS	-0.0001	–	–	–	0.0005**	0.0006***	–	–
	(0.0002)	–	–	–	(0.0002)	(0.0000)	–	–
MARRIED	0.0242	0.0185***	0.0237***	0.0198***	0.0883***	0.0872***	0.0521***	0.0409***
	(0.0241)	(0.0064)	(0.0084)	(0.0062)	(0.0213)	(0.0170)	(0.0071)	(0.0049)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
MARRIED×ROOMS	-0.0002	–	–	–	-0.0109*	-0.0133***	–	–
	(0.0064)	–	–	–	(0.0057)	(0.0045)	–	–
DIVORCED	0.0060	–	0.0089	–	0.0131	–	0.0145	–
	(0.0120)	–	(0.0118)	–	(0.0097)	–	(0.0096)	–
WIDOW	0.0675	0.0492**	0.0547***	0.0498**	-0.2394*	–	0.0325	–
	(0.0628)	(0.0196)	(0.0206)	(0.0195)	(0.1280)	–	(0.0297)	–
WIDOW×ROOMS	-0.0051	–	–	–	0.0642**	–	–	–
	(0.0172)	–	–	–	(0.0291)	–	–	–
ARAB	0.0575**	0.0833***	0.0774***	0.0782***	0.0665***	0.0310***	0.0306***	0.0333***
	(0.0279)	(0.0067)	(0.0073)	(0.0070)	(0.0244)	(0.0057)	(0.0063)	(0.0056)
ARAB×ROOMS	0.0063	–	–	–	-0.0100	–	–	–
	(0.0074)	–	–	–	(0.0067)	–	–	–
OTHER	0.0731	0.1146**	-0.0024	–	0.0637	–	0.0046	–
	(0.0564)	(0.0519)	(0.0146)	–	(0.0512)	–	(0.0161)	–
OTHER×ROOMS	-0.0245	-0.0352**	–	–	-0.0185	–	–	–
	(0.0157)	(0.0146)	–	–	(0.0152)	–	–	–
IMM_EUROPE_AMERICA	0.0494*	0.0389***	0.0338***	0.0366***	0.0212	0.0163***	0.0141**	0.0171***
	(0.0288)	(0.0072)	(0.0075)	(0.0070)	(0.0261)	(0.0061)	(0.0066)	(0.0060)
EUROPE×ROOMS	-0.0039	–	–	–	-0.0015	–	–	–
	(0.0071)	–	–	–	(0.0064)	–	–	–
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	full	step-wise	full	step-wise	full	step-wise	full	step-wise
VARIABLES	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)	ln(BMI)
IMM_ASIA_AFRICA	0.0958	–	-0.0185	–	0.0342	–	-0.0187*	–
	(0.0615)	–	(0.0148)	–	(0.0413)	–	(0.0095)	–
ASIA×ROOMS	-0.0305**	–	–	–	-0.0133	-0.0053**	–	–
	(0.0151)	–	–	–	(0.0102)	(0.0023)	–	–
DOMSHELP	-0.0286	–	-0.0014	–	-0.0108	–	-0.0085	–
	(0.0434)	–	(0.0087)	–	(0.0268)	–	(0.0065)	–
AGE×ROOMS	0.0065	–	–	–	0.0001	–	–	–
	(0.0097)	–	–	–	(0.0062)	–	–	–
HHSIZE	-0.0045	–	0.0047**	0.0045***	0.0014	–	0.0007	–
	(0.0074)	–	(0.0019)	(0.0016)	(0.0059)	–	(0.0015)	–
HHSIZE×ROOMS	0.0024	0.08219×10^{-2}**	–	–	-0.0002	–	–	–
	(0.0019)	(0.0004)	–	–	(0.0016)	–	–	–
BELOW_17	0.0010*	0.1069×10^{-2}***	-0.0000	–	-0.0007	–	-0.0002*	–
	(0.0005)	(0.0003)	(0.0001)	–	(0.0005)	–	(0.0001)	–
BELOW_17×ROOMS	-0.0003**	-0.0268×10^{-2}***	–	–	0.0001	–	–	–
	(0.0001)	(0.0001)	–	–	(0.0001)	–	–	–
Gender	FEMALE	FEMALE	FEMALE	FEMALE	MALE	MALE	MALE	MALE
Interaction with Rooms	YES	YES	NO	NO	YES	YES	NO	NO
Observations	4,238	4,238	4,238	4,238	4,550	4,550	4,550	4,550
VIF	20.55	5.95	5.65	1.20	22.67	5.78	5.94	1.15
R-squared	0.1625	0.159	0.159	0.158	0.0966	0.0924	0.0924	0.0897
F-statistic	31.55	82.50	47.78	114.7	19.24	68.61	28.36	92.16

Notes: The Variance Inflating Factor (VIF) measures the level of collinearity, where VIF above 10 indicates high degree of collinearity. Robust standard errors are given in parentheses. * significant at the 10% significance level. ** significant at the 5% significance level. *** significant at the 1% significance level.

Results indicate opposite effects of suburbanization on the BMI of women and men moving to larger apartment with more rooms. While projected BMI of females is expected to drop significantly by 0.13%×ROOMS_SQ with each additional room (significant at the 1% significance level), projected BMI of males is expected to rise significantly with each additional room by 0.65% (significant at the 1% significance level). Recent empirical studies (e.g., Sallis *et. al.*, 2016; Creatore et. al., 2016) have demonstrated a negative relationship between suburbanization and the level of physical activities including walkability. Once again, the findings in our study concerning women may stand at odds with previous medical findings. Yet, they provide justification to the model that includes interaction terms with the number of rooms.

Figure 4 simulates the effect of an increase in the number of rooms on the projected level of BMI of 20-year-old married men and women. Projections were obtained from columns (4) and (8) in Table 3. Each projected value was transformed from ln(BMI) to BMI by the exponential function. The upper figure describes the aggregated projected BMI of both gender with the number of rooms. This aggregated figure is a parabola with a maximal aggregated BMI for 3-room apartment, and a minimal aggregated BMI for an apartment with one- and five-rooms. The middle (lower) figure describes projected BMI of 20-year-old female (male) with the number of rooms. Note, that the 20-year-old married male with five rooms apartment is expected to be overweight (95% confidence interval of $24.64 \leq proj(BMI) \leq 25.21$ where $proj(BMI) \geq 25$ is defined as overweight. Consequently, and in spite of the resemblance of the aggregated BMI for one- and five-room apartments, if the criteria for housing choice is a minimal aggregated BMI, the optimal choice of the household is expected be a one-room apartment (Note 11):

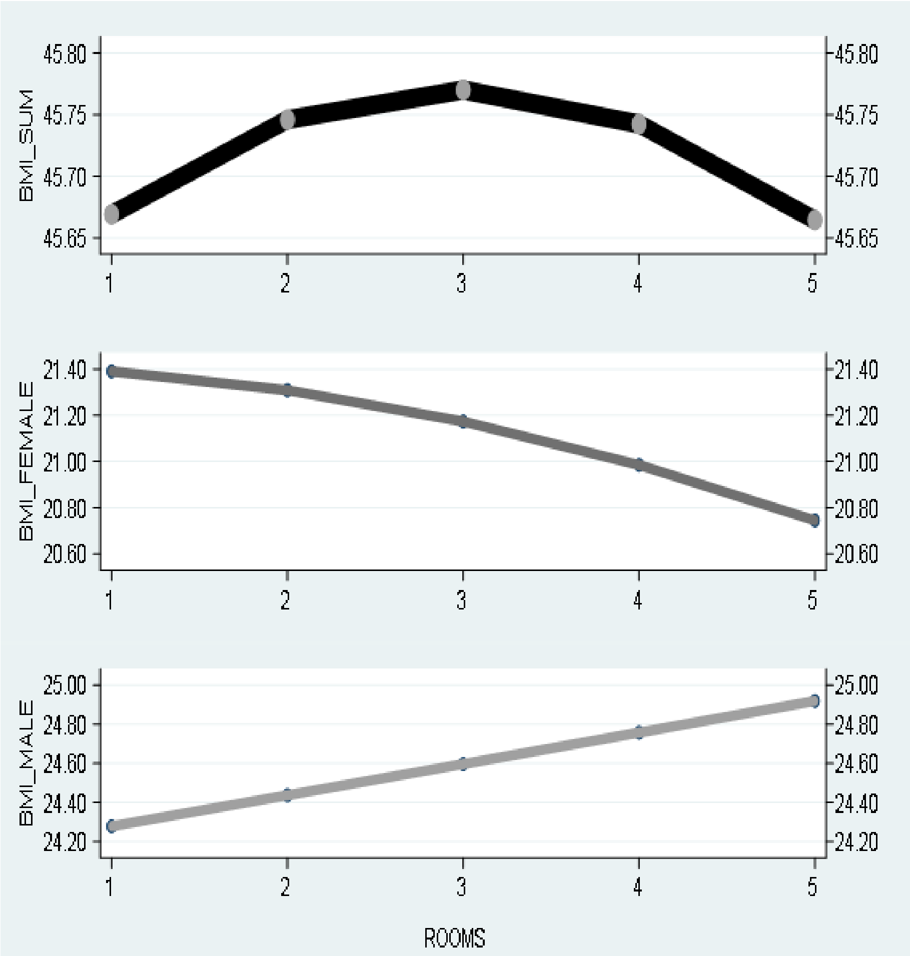

Figure 4. Variation of Females and Males BMI with the Number of Rooms

Notes: The figure simulates the effect of increase in the number of rooms on the Projected level of BMI of 20-year-old married female and male. Projections were obtained from columns (4) and (8) in Table 3. Each projected value was transformed from ln(BMI) to BMI by the exponential function. The upper figure describes the aggregated projected BMI of both gender with the number of rooms. The middle (lower) figure describes projected BMI of 20-year-old female (male) with the number of rooms. Note, that the 20-year-old married male with five rooms apartment is expected to be overweight (95% confidence interval of $24.64 \le proj(BMI) \le 25.21$ where $proj(BMI) \ge 25$ is defined as overweight. Consequently, the optimal choice would be a one-room apartment.

Additional findings from Table 3 suggest that, as expected, projected BMI rises significantly by 0.21%-0.52% with each addition year-of-age, and by 1.85%-8.83% with a shift from single to married status for both genders. Compared with single females, projected BMI of a widow is expected to increase by 4.92%-5.47%. Compared with their Jewish counterparts, projected BMI of Arabs are higher significantly by 3.06%-8.33% for both genders. Compared with native Israelis, projected BMI of immigrants from European or American countries are higher significantly by 1.41%-3.89% for both genders. All the coefficients are statistically significant at the 5%-1% significance level.

Referring to female with children, an interesting outcome has been obtained from the interaction terms with the number of rooms. Each additional family member is expected to raise significantly the projected BMI of the female household member living in a one-room apartment by 0.0829% (at the 5% significance level). A one percent increase in the BELOW_17 variable is expected to raise significantly the projected BMI of the female household member by 0.10693% (significant at the 5% significance level). In contrast, a one percent increase in the BELOW_17 variable is expected to drop the projected BMI of the female household member with each additional room by 0.02681% (significant at the 1% significance level).

Figure 5 simulates the outcomes obtained from the latter coefficients. The simulation refers to married women living in a 3.5-room apartment (the sample mean) with increasing number of children. For each additional child, on the one hand, projected BMI is expected to rise significantly by 0.28768% (the coefficient of HHSIZE×ROOMS multiplied by 3.5), and by $0.10693\% \times 100 \times (C/(C+2))$ (the coefficient of the BELOW_17 variable multiplied by $100 \times (C/(C+2))$, where C is the number of children. On the other hand, the component of drop in the projected BMI with the total number of children is given by the formula $-0.02681\% \times 100 \times (C/(C+2)) \times 3.5$. The figure demonstrates a total increase in the projected BMI from 9.6349% (the first child) to 22.72% (the eight child), where the rise occurs at a decreasing paste for each additional child. Interestingly, this result stands in contract to those reported in Figure 3 for males with children.

4. Summary and Conclusions

Recent medical studies have examined ways to offer more spatial planning opportunities to increase physical activities. (e.g., Sallis *et. al*, 2016; Creatore *et. al.*, 2016). Yet, to the best of our knowledge, apart from these effects, the impact of dwelling unit characteristics (e.g., type and size), combined with socio-demographic variables (e.g., the number of children, marital status, place of birth, origin, and gender) on the body mass index (BMI) has not been previously examined. Thus, the objective of the current study is twofold: to demonstrate that in addition to other spatial planning factors design of dwelling unit types plays an important role in determining walkability and BMI levels; to reveal the different impact of the structure design factor across gender based on the conventional approach in the literature.

The outcomes of our study indicate opposite effects of suburbanization on the BMI of women and men moving from multi-family condominiums to single family units and larger apartments. While projected BMI of females is expected to drop significantly with the movement from condominiums to single family units (by 1.30%-1.46%) and with additional rooms (by 0.13% ×ROOM_SQ), projected BMI of males is expected to rise significantly with the movement from condominiums to single family units (by 1.04%-1.16%) and with additional rooms (by 0.65%).

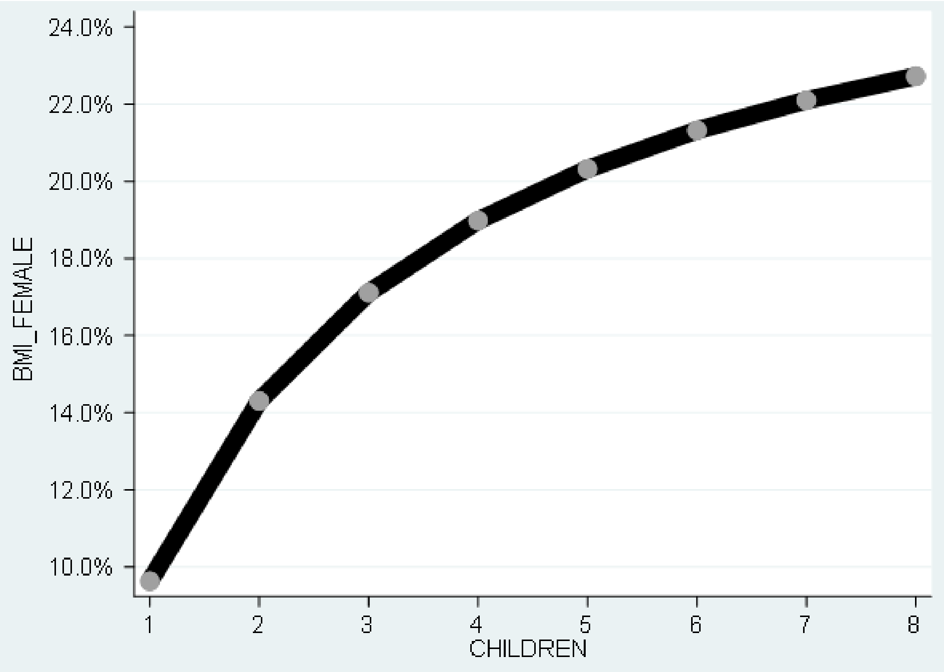

Figure 5. Variation of Females BMI with the Number of Children in Apartments with 3.5 Rooms

Notes: The simulation is based on column (2) in Table 3. The objective is to demonstrate the BMI drop of females living in apartment with 3.5 rooms (kitchen and bathrooms are not counted as rooms) (the sample mean) with each additional child. Data for the figure is given in the table 5.

Table 5.

CHILDREN (C)	(1)=coef of HHSIZE× 3.5	(2)=0.10693% × 100 × $(C/(C+2))$	(3)=−0.02681% × 100 × $(C/(C+2))$ ×3.5	(4)=(1)+(2)+(3)
1	0.28768%	12.47555%	−3.12833%	9.6349%
2	0.28768%	18.71332%	−4.69249%	14.30851%
3	0.28768%	22.45599%	−5.63099%	17.11268%
4	0.28768%	24.9511%	−6.25665%	18.98213%
5	0.28768%	26.73332%	−6.70356%	20.31744%
6	0.28768%	28.06998%	−7.03874%	21.3182%
7	0.28768%	29.10961%	−7.29943%	22.09786%
8	0.28768%	29.94132%	−7.50799%	22.72101%

Two possible interpretations may be given to these findings. According to the more economic and behavioral interpretation, given the considerable female-male wage gaps (Sharabani, 2007; Blau and Kahn, 2017), a possible decision-making with repercussions on walkability at home would center around a couple decision to assign roles with regard to addressing BMI with the husband focusing on employment outside the home. Consequently, the wife spending more hours at home or engaged in leisure-time physical activity in the case that larger or single-family apartments represent a proxy for wealth (see, for example, Au and Johnson, 2015). Another possible interpretation is the differences in the physiological responses of females and males under equal conditions. Many medical studies documented such physiological differences (e.g., Renehan *et. al.*, 2008; Hatch et. al., 2010).

Additional findings suggest a significant 11.69%-3.59% drop in the projected BMI among both females and males originating from Asian and African countries with relocation from condominiums to single family homes. Once again, these findings might stand at odd with previous medical findings referring to denser communities with higher population densities and mixed uses. One possible interpretation is that single family homes provide a more rural like environment to people who immigrated from Asian and African countries.

Finally, the projected BMI of a male living in a single family home drops significantly with an increasing number of children and at a decreasing rate. A possible interpretation is that fathers with larger single housing units tend to be more active and play with their children. In contrast, the projected BMI of a female living in a 3.5 rooms apartment (the sample mean) rises significantly with more children at a decreasing paste.

One aspect of our research is related to the decision in what type and size of apartment to live so as to decrease the BMI. Given the opposite effects of housing type and size on gender, a simple criterion to make an optimal choice of apartment for married couples is the minimal aggregated projected BMI of both gender for each type of structure and number of rooms. An appropriate simulation suggests that for a 20-year old married couple or older without children, the optimal BMI is obtained for a single family home and an apartment with one room.

Another aspect of our research is related to public policy. Research findings suggest that as long as obesity is considered to be a serious pandemic, city planners should account for the impact of dwelling unit characteristics as-well-as other spatial planning factors on walkability and BMI levels. Also, and given the opposite effects of housing type and size on gender, among other factors, the housing choice of married couple should account for the optimal level of BMI for both genders.

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Notes

Note 1. This suburbanization process itself spurred the creation of urban economics as a separate discipline in economics. Mills and Hamilton (1989), for example, provide a formal proof to the statement that under realistic conditions, high income households live further from the city center than do low-income households. Baum-Snow (2007) estimated that had the US interstate highway systems not been built during the 1950s and 1960s, aggregate central city population would have increased by 8% from 1950-1990 – rather than declining by 17% (McDonald and McMillen, 2011; page 318).

Note 2. On the other hand, based on a longitudinal survey carried out among movers from one neighborhood to another, Eid *et. al.*, 2008 found no relationship between obesity and urban sprawl.

Note 3. "Body Mass Index" (BMI) is a convential measure of obesity. It is calculated as $\frac{WEIGHT}{HEIGHT^2}$ where WEIGHT is measured in kilograms and HEIGHT is measured in meters. A widely adopted definition of overweight is a body mass index (BMI) greater than or equal to 25, with obesity defined as BMI $\geq$30 (Qin and Pan, 2016; page 1293; OECD, 2016; page 98).

Note 4. Based on appropriate key words, we found 6,685 studies in PubMed that report on gender differences in the context of BMI and obesity.

Note 5. Blau and Kahn (2017) analyzed a time-series of gender wage gaps. The authors show a reduction in the US wage-gap from 66%=$\frac{40\%}{60\%}$ in 1980 to 25%=$\frac{20\%}{80\%}$ in 2010. Equivalent figures in Israel suggest a 30-34% gap in 1995 among 30-44 year-old adults with above 15 years of schooling (Shahrabani, 2007, Table 2, page 114). Given this state of events, a possible decision-making with repercussions on walkability would center around assigning roles with regard to addressing BMI with the husband focusing on employment outside the home. Consequently, the wife would spend more hours either at home or in leisure-time physical activity in the case that larger apartment represents a proxy for wealth (see, for example, Au and Johnson, 2015).

Note 6. To be strongly balanced, Y2016 should be equal statistically to 0.5; namely, each observation×year should have exactly two observations – one for each year.

Note 7. The respective 95% and 99% confidence intervals for females are: (24.68, 24.96) and (24.63, 25.01) and for males are: (26.19, 26.43) and (26.16, 26.46).

Note 8. The OECD report, 2016 states that: "Obesity is a known risk factor for numerous health problems, including hypertension, high cholesterol, diabetes, cardiovascular diseases and some forms of cancer. Because obesity is associated with higher risks of chronic illnesses, it is linked to significant additional health care costs." (page 98).

Note 9. Rooms include living rooms and bedrooms but not kitchen or bathrooms.

Note 10. The Pearson correlation between *SINGLE_FAMILY* and *ROOMS* is positive and statistically significant at the 1% significance level for both genders, i.e., +30.0% for females and +28.90% for males. In contrast, the Pearson correlation between *SINGLE_FAMILY* and *CONDOMINIUMS* is negative and statistically significant at the 1% significance level for both genders, i.e., –32.23% for females and –31.62% for males. When we supplement the variables *ROOMS* and *ROOMS_SQ*, the coefficient of *SINGLE_FAMILY* becomes statistically insignificant for both genders. We thus estimate separately the models that include and exclude the variables *ROOMS* and *ROOMS_SQ*.

Note 11. An extension of this model is given in Arbel *et. al.*, 2018.

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