

Relationship between Meeting Physical Activity Guideline Parameters and Body Mass Index (BMI) in Adults

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Received September 02, 2021; Revised October 05, 2021; Accepted October 13, 2021

Abstract Background: Physical activity (PA) and risk of obesity are inversely related in adult populations. However, the extent to which meeting different PA guidelines influence body mass index (BMI) is less known. The aim of this research was to examine how different PA guideline parameters affect BMI in adults. **Methods:** The Montana Behavioral Risk Factor Surveillance System (BRFSS, 2019) was used for this study. Four different PA guideline variables were used and included 1) 2-level aerobic PA (APA) (met APA or did not meet APA), 2) 2-level muscle strengthening activity (MSA) (met MSA or did not meet MSA), 3) 4-level PA (met both APA and MSA, met APA only, met MSA only, or met neither), and 4) 3-level APA categories (active, insufficiently active, or inactive). BMI was calculated from self-reported height and weight (kg/m^2). Multiple linear regression was used to examine the effect of each PA guideline parameter on BMI while controlling for sociodemographic variables. **Results:** Findings showed that meeting the 2-level APA (slope (b) = -0.74 kg/m^2 , $p < .0001$) or the 2-level MSA (b = -0.75 kg/m^2 , $p < .0001$) guideline was associated with lower mean BMI. In the 4-level PA model, as compared to meeting neither guideline, meeting APA only (b = -0.58 kg/m^2 , $p = .0119$) or meeting both APA and MSA (b = -1.32 kg/m^2 , $p < .0001$) was associated with lower mean BMI. Meeting MSA only did not show significantly ($p = .1748$) different BMI from those meeting neither guideline. In the 3-level APA model, as compared to those categorized as inactive, those categorized as active (b = -0.91 kg/m^2 , $p < .0001$) had lower mean BMI. Those categorized as insufficiently active did not have significantly ($p = .1748$) different BMI from those categorized as inactive. Furthermore, the 4-level PA guidelines \times sex interaction was significant ($p = .030$) and indicated lower mean BMI for females meeting either MSA only (b = -1.05 kg/m^2 , $p = .0215$), APA only (b = -1.14 kg/m^2 , $p = .0014$), or both APA and MSA (b = -1.84 kg/m^2 , $p < .0001$) guideline (p for trend $< .0001$). Whereas for males, only meeting both APA and MSA was associated with lower mean BMI (b = -0.77 kg/m^2 , $p = .0077$). **Conclusion:** This study found that meeting either APA or MSA guideline is associated with lower BMI in adults. However, sex-specific analyses indicate that this is true for females only and in dose-response fashion. Lower BMI in males is only associated with meeting both APA and MSA guidelines. Health promotion specialists concerned with obesity should understand the influence that each PA guideline has on relative body weight. Physical activity programming should promote both APA and MSA among adults in Montana.

Keywords: body mass index (BMI), physical activity (PA), muscle strengthening activity (MSA), BRFSS, Montana

Cite This Article: Peter D. Hart, "Relationship between Meeting Physical Activity Guideline Parameters and Body Mass Index (BMI) in Adults." *Journal of Physical Activity Research*, vol. 6, no. 2 (2021): 130-134. doi: 10.12691/jpar-6-2-11.

1. Introduction

Obesity is linked to several different health problems in adults and in response the United States (U.S.) has set a goal for reducing its prevalence from approximately 38% (2016) to 36% by year 2030 [1]. One behavioral approach for reducing obesity is increasing physical activity (PA). Many cross-sectional studies have reported an inverse PA and obesity relationship [2,3,4]. Moreover, interventions using PA as a component show weight-related improvements in obese populations [5,6]. Body mass index (BMI) is a

common measure used to classify obesity, especially in large populations [7]. BMI is computed as body mass in kilograms over height in meters squared ($\text{BMI} = \text{kg/m}^2$). Studies have also reported inverse associations between PA and BMI [8,9,10].

The 2018 Physical Activity Guidelines for Americans state that adults do 150+ minutes of moderate-intensity or 75+ minutes of vigorous-intensity, or an equivalent combination of moderate-to-vigorous-intensity PA (MVPA) each week [11]. These PA guidelines are recommended for their health advantages, which include body weight benefits. Some studies have shown an inverse relationship between meeting PA guidelines and obesity [12,13,14].

However, less is known about the relationship between meeting PA guidelines and BMI in adults. Additionally, no studies have examined the extent to which meeting different PA guidelines influences BMI in adults. Therefore, the purpose of this study was to examine how different PA guideline parameters relate to BMI in an adult population.

2. Materials & Methods

Data for this study came from the Behavioral Risk Factor Surveillance System (BRFSS, 2019). BRFSS methodological details can be found elsewhere [12,13]. The BRFSS is a state-based annual telephone survey aimed at collecting data about health factors related to the leading causes of premature morbidity and mortality. The BRFSS samples noninstitutionalized U.S. adults 18+ years of age. The Montana BRFSS data were extracted from the larger dataset for this study and BMI was restricted to $< 40 \text{ kg/m}^2$.

Four different PA guideline variables were used in this study. A two-level aerobic PA (APA) variable was constructed and participants were classified as either those that “met APA” or “did not meet APA” guidelines. A two-level muscle strengthening activity (MSA) variable was constructed and participants were classified as either those that “met MSA” or “did not meet MSA” guidelines. A four-level PA variable was constructed and participants were classified as either those that “met both APA and MSA”, “met APA only”, “met MSA only”, or “met neither” guideline. Finally, a three-level APA categories variable was constructed and participants were classified as either those that are “active”, “insufficiently active”, or “inactive”. Meeting APA was determined from a series of questions asking participants about their PA and exercise during the previous month. After reporting the types of activities, the usual frequency, and usual duration, a total minutes of PA per week was computed for each respondent. Those reporting 150+ minutes of total MVPA per week were considered “active” and “met APA” guidelines. Those reporting some PA but less than 150 minutes of total MVPA per week were considered “insufficiently active” and “did not meet APA” guidelines. Those reporting no PA were considered “inactive” and “did not meet APA” guidelines.

Meeting MSA was determined from a series of questions asking participants about their muscle strengthening PA and exercise during the previous month. Participants reporting 2+ days per week of MSA were considered those that “met MSA” guidelines and participants reporting less than 2 days per week were considered those that “did not meet MSA” guidelines. BMI was calculated from self-reported height and weight (kg/m^2). Study covariates included sex, age, race/ethnicity, income, education, and rural/urban status.

Statistical analyses included means, standard errors (SEs) and 95% confidence intervals (CIs) for BMI across APA and MSA parameter status. Test for difference in means were performed using regression analysis *t* statistics. Multiple linear regression was used to estimate the mean BMI difference (unstandardized slope, *b*) for each PA guideline parameter in separate models. All

multiple regression models were controlled for sex, age, race/ethnicity, income, education, and rural/urban status. Analyses were weighted to produce generalizations representative of noninstitutionalized adults in Montana. SAS version 9.4 and SPSS version 27 were used for all analyses [14,15,16,17].

3. Results

Overall, a total of $N = 5,772$ participants ($\text{BMI} < 40 \text{ kg/m}^2$) had complete BMI ($\text{Mean} = 26.95$, $95\% \text{ SE} = 0.076$) data and pairwise deletion was used for all other analyses. Table 1 contains mean BMI comparisons by APA guideline status overall and across sociodemographic characteristics. Montana adults meeting APA guidelines ($\text{Mean} = 26.66$, $\text{SE} = 0.09$) had significantly ($p < .0001$) lower BMI than those not meeting APA guidelines ($\text{Mean} = 27.43$, $\text{SE} = 0.14$). Additionally, females meeting APA guidelines ($\text{Mean} = 26.03$, $\text{SE} = 0.14$) had significantly ($p < .0001$) lower BMI than those not meeting APA guidelines ($\text{Mean} = 27.25$, $\text{SE} = 0.21$). Whereas no APA status differences were seen for males. Race/ethnicity groups saw little APA status difference, with exception for the White race group, with those meeting APA guidelines ($\text{Mean} = 26.62$, $\text{SE} = 0.10$) having significantly ($p < .0001$) lower BMI than those not meeting APA guidelines ($\text{Mean} = 27.33$, $\text{SE} = 0.15$).

Table 2 contains mean BMI comparisons by MSA guideline status overall and across sociodemographic characteristics. Montana adults meeting MSA guidelines ($\text{Mean} = 26.41$, $\text{SE} = 0.12$) had significantly ($p < .0001$) lower BMI than those not meeting MSA guidelines ($\text{Mean} = 27.29$, $\text{SE} = 0.10$). Additionally, females meeting MSA guidelines ($\text{Mean} = 25.79$, $\text{SE} = 0.18$) had significantly ($p < .0001$) lower BMI than those not meeting MSA guidelines ($\text{Mean} = 26.96$, $\text{SE} = 0.16$). Similarly, males meeting MSA guidelines ($\text{Mean} = 26.92$, $\text{SE} = 0.15$) had significantly ($p = .0008$) lower BMI than those not meeting MSA guidelines ($\text{Mean} = 27.60$, $\text{SE} = 0.13$). Race/ethnicity groups once again saw little difference for MSA status, with exception again for the White race group, with those meeting MSA guidelines ($\text{Mean} = 26.31$, $\text{SE} = 0.12$) having significantly ($p < .0001$) lower BMI than those not meeting MSA guidelines ($\text{Mean} = 27.24$, $\text{SE} = 0.11$).

Table 3 contains results for the four models of BMI regressed on the different PA guideline parameters. Findings showed that meeting the 2-level APA (slope (*b*) = -0.74 kg/m^2 , $p < .0001$) or the 2-level MSA (*b* = -0.75 kg/m^2 , $p < .0001$) guideline was associated with lower mean BMI. In the 4-level PA model, as compared to meeting neither guideline, meeting APA only (*b* = -0.58 kg/m^2 , $p = .0119$) or meeting both APA and MSA (*b* = -1.32 kg/m^2 , $p < .0001$) was associated with lower mean BMI. Meeting MSA only did not show significantly ($p = .1748$) different mean BMI from those meeting neither guideline. In the 3-level APA model, as compared to those categorized as inactive, those categorized as active (*b* = -0.91 kg/m^2 , $p < .0001$) had lower mean BMI. Those categorized as insufficiently active did not have significantly ($p = .1748$) different mean BMI from those categorized as inactive.

Table 1. Body mass index (BMI) comparison by aerobic physical activity (APA) guideline status in Montana adults, 2019

Sociodemographic variable	Met APA Guidelines			Did not meet APA Guidelines			Difference	
	<i>N</i>	<i>Mean</i>	<i>SE</i>	<i>N</i>	<i>Mean</i>	<i>SE</i>	<i>Mean</i>	<i>p</i>
Overall	3,460	26.66	0.09	1,992	27.43	0.14	-0.77	< .0001
Sex								
Males	1,795	27.22	0.12	1,017	27.59	0.17	-0.37	.0806
Females	1,665	26.03	0.14	975	27.25	0.21	-1.21	< .0001
Age Group (yr)								
18 to 24	228	25.15	0.33	146	25.72	0.46	-0.57	.3144
25 to 34	375	26.45	0.27	192	26.30	0.36	0.14	.7488
35 to 44	433	26.51	0.24	244	27.33	0.34	-0.82	.0519
45 to 54	390	27.33	0.27	238	28.61	0.35	-1.28	.0039
55 to 64	715	27.36	0.19	415	28.16	0.30	-0.80	.0235
65+	1,319	26.79	0.15	757	27.92	0.22	-1.13	< .0001
Race/Ethnicity								
White	2,997	26.62	0.10	1,648	27.33	0.15	-0.70	< .0001
American Indian	213	28.00	0.51	185	28.11	0.58	-0.11	.8863
Hispanic	72	26.24	0.58	42	28.10	0.89	-1.86	.0800
Multiracial	84	27.12	0.66	64	28.21	0.97	-1.09	.3521
Income (\$)								
<15,000	214	26.56	0.50	178	27.48	0.48	-0.92	.1843
15,000 to 24,999	400	26.47	0.32	332	27.51	0.36	-1.03	.0319
25,000 to 34,999	331	26.65	0.30	208	28.00	0.43	-1.34	.0105
35,000 to 49,999	477	26.91	0.25	282	27.47	0.36	-0.57	.1950
50,000+	1,648	26.83	0.12	740.00	27.54	0.20	-0.71	.0028
Education								
Did not graduate high school	108	27.44	0.54	139	27.14	0.55	0.30	.6936
Graduated high school	855	26.79	0.19	594	27.60	0.26	-0.82	.0115
Attended some college	1,045	26.83	0.17	650	27.75	0.22	-0.92	.0009
Graduated college	1,448	26.24	0.13	607	26.89	0.22	-0.65	.0110
Rural Status								
Urban	1,904	26.45	0.12	1,006	27.21	0.18	-0.76	.0003
Rural	1,556	27.04	0.16	986	27.82	0.21	-0.78	.0028

Note. Body mass index (BMI) computed from self-reported height and weight (kg/m²). Population restricted to BMI < 40 kg/m². Mean differences in bold are significant ($p < .05$).

Table 2. Body mass index (BMI) comparison by muscle strengthening activity (MSA) guideline status in Montana adults, 2019

Sociodemographic variable	Met MSA Guidelines			Did not meet MSA Guidelines			Difference	
	<i>N</i>	<i>Mean</i>	<i>SE</i>	<i>N</i>	<i>Mean</i>	<i>SE</i>	<i>Mean</i>	<i>p</i>
Overall	2,162	26.41	0.12	3,326	27.29	0.10	-0.88	< .0001
Sex								
Males	1,162	26.92	0.15	1,669	27.60	0.13	-0.68	.0008
Females	1,000	25.79	0.18	1,657	26.96	0.16	-1.17	< .0001
Age Group (yr)								
18 to 24	175	24.82	0.37	197	25.80	0.39	-0.99	.0669
25 to 34	244	25.80	0.30	317	26.68	0.30	-0.88	.0379
35 to 44	275	26.43	0.29	395	27.12	0.28	-0.69	.0842
45 to 54	247	27.08	0.33	400	28.19	0.28	-1.11	.0105
55 to 64	414	27.36	0.25	727	27.82	0.21	-0.46	.1614
65+	807	26.80	0.19	1,290	27.48	0.16	-0.68	.0064
Race/Ethnicity								
White	1,826	26.31	0.12	2,861	27.24	0.11	-0.93	< .0001
American Indian	162	27.44	0.61	232	28.59	0.51	-1.14	.1505
Hispanic	48	26.56	0.71	63	27.46	0.73	-0.90	.3766
Multiracial	60	27.55	0.75	89	27.27	0.80	0.28	.8001
Income (\$)								
<15,000	166	26.36	0.49	229	27.39	0.49	-1.02	.1397
15,000 to 24,999	255	26.17	0.40	475	27.42	0.30	-1.25	.0121
25,000 to 34,999	212	26.82	0.39	328	27.31	0.32	-0.49	.3338
35,000 to 49,999	280	26.90	0.31	485	27.23	0.27	-0.33	.4280
50,000+	1,002	26.52	0.15	1,389	27.40	0.14	-0.88	< .0001
Education								
Did not graduate high school	90	27.95	0.62	166	27.15	0.49	0.79	.3124
Graduated high school	534	26.28	0.23	918	27.59	0.20	-1.31	< .0001
Attended some college	641	26.57	0.21	1,051	27.49	0.18	-0.92	.0009
Graduated college	895	26.02	0.16	1,185	26.75	0.16	-0.72	.0010
Rural Status								
Urban	1,214	26.23	0.14	1,724	27.04	0.13	-0.81	< .0001
Rural	948	26.76	0.20	1,602	27.71	0.16	-0.95	.0002

Note. Body mass index (BMI) computed from self-reported height and weight (kg/m²). Population restricted to BMI < 40 kg/m². Mean differences in bold are significant ($p < .05$).

Table 3. Body mass index (BMI) regressed on the different meeting PA guideline parameters in Montana adults, 2019

PA guideline parameters	<i>N</i>	<i>Slope (b)</i>	<i>SE</i>	<i>t</i>	<i>p</i>
APA guideline					
Met APA	2,995	-0.741	0.175	-4.23	< .0001
Did not meet APA	1,701	ref			
MSA guideline					
Met MSA	1,862	-0.745	0.164	-4.54	< .0001
Did not meet MSA	2,842	ref			
PA guidelines					
Met both APA and MSA	1,325	-1.314	0.230	-5.71	< .0001
Met APA only	1,598	-0.577	0.229	-2.52	.0119
Met MSA only	500	-0.407	0.300	-1.36	.1748
Met neither	1,173	ref			
APA guideline categories					
Active	2,953	-0.911	0.224	-4.06	< .0001
Insufficiently active	668	-0.296	0.297	-1	.3196
Inactive	1,033	ref			

Note. Body mass index (BMI) computed from self-reported height and weight (kg/m^2). Population restricted to BMI < 40 kg/m^2 . All models controlled for sex, age, race/ethnicity, income, education, and rural/urban status. Slope values in bold are significant ($p < .05$).

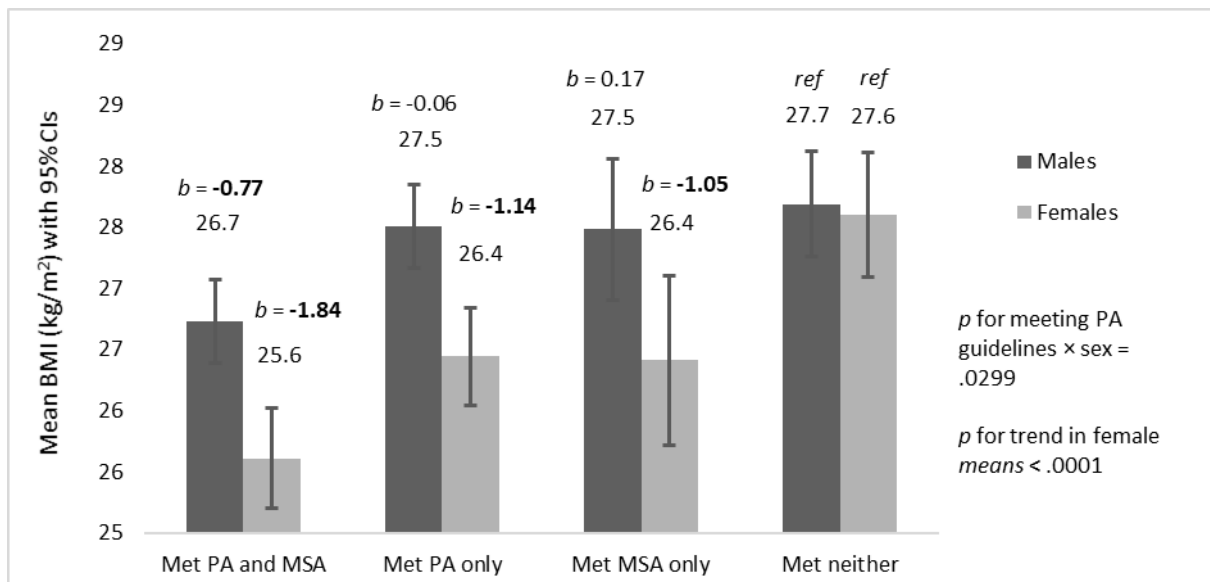


Figure 1. Mean BMI across 4-level PA guidelines status by sex in Montana adults, 2019 (Note. $N = 4,596$. Body mass index (BMI) computed from self-reported height and weight (kg/m^2). Adjusted unstandardized slopes (b s) are by sex and controlled for age, race/ethnicity, income, education, and rural/urban status. Slope values in bold are significantly ($p < .05$) different from their sex-specific reference (ref). Population restricted to BMI < 40 kg/m^2 .)

Figure 1 displays mean BMI across 4-level PA guidelines status by sex. This graph shows visually the apparent PA guidelines status \times sex interaction ($p = .030$) resulting in sex-specific analyses. In the females model, results showed lower adjusted mean BMI for those meeting MSA only ($b = -1.05 \text{ kg}/\text{m}^2$, $p = .0215$), APA only ($b = -1.14 \text{ kg}/\text{m}^2$, $p = .0014$), or both APA and MSA ($b = -1.84 \text{ kg}/\text{m}^2$, $p < .0001$) guideline. Additionally, mean BMI decreased in dose-response fashion (p for trend < .0001) for females. In the males model, results showed lower adjusted mean BMI ($b = -0.77 \text{ kg}/\text{m}^2$, $p = .0077$) for those meeting both APA and MSA only.

4. Discussion

The purpose of this study was to examine how meeting different PA guideline parameters relate to BMI in adults. Results clearly indicate that meeting either PA guideline is

associated with lower BMI and remains so after full sociodemographic adjustment. Several specific findings however are worth discussing. Firstly, these data indicate that meeting both APA and MSA relates to more than twice the effect on BMI as compared to meeting APA only. This finding supports the 2018 recommendation for adults, which promotes both guidelines, in terms of maintaining a healthy body weight [21]. Secondly, overall, meeting MSA guidelines only was not related to BMI when compared to being inactive. There are two possible explanations for this finding. One is that adults participating in MSA may have similar BMI to inactive adults, but because they have more muscle mass, which in turn increases body mass and BMI [22]. Although this is a familiar argument, it does not explain why those meeting both APA and MSA have such lower BMI than their MSA only and inactive counterparts. Two is that the low relative sample size for adults meeting MSA only decreased the chances of finding an MSA only effect on BMI [23].

Regardless, however, the effect size for this relationship was smaller than its comparison categories. Thirdly, similar to the previous note, adults classified as insufficiently active had similar BMI to those classified as inactive. This finding supports the 150+ minutes of moderate-intensity (or vigorous-intensity equivalent) APA threshold recommended of all adults. Lastly, sex-specific analyses on the four-level PA guideline parameter showed that meeting either APA only or MSA only as well as meeting both APA and MSA related to lower BMI in females. Conversely, in males, lower BMI was only associated with meeting both APA and MSA guidelines. Despite these findings, an indirect dose-response relationship was seen in females, where meeting MSA only had the smallest effect on BMI, meeting APA only had a slightly larger effect on BMI, and meeting both APA and MSA had a pretty substantial effect on BMI. Therefore, although meeting either PA guideline was seen to have BMI benefit, meeting both guidelines should be considered optimal in both male and female adults.

5. Conclusions

This study found that meeting either APA or MSA guideline is associated with lower BMI in adults. However, sex-specific analyses indicate that this is true for females only and in dose-response fashion. Lower BMI in males is only associated with meeting both APA and MSA guidelines. Health promotion specialists concerned with obesity should understand the influence that each PA guideline has on relative body weight. Physical activity programming should promote both APA and MSA among adults in Montana.

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