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Relationship between muscular fitness, health behaviors, and health-related quality of life in U.S. Women

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Abstract
Background: Grip strength is a measure of muscular fitness and is related to many health problems in women. The primary purpose of this study was to examine the relationship between grip strength and HRQOL in U.S. women. A secondary purpose was to examine the extent to which physical activity (PA), obesity, and smoking moderate the grip strength and HRQOL relationship.
Methods: Data for this research came from women 20 years of age and older participating in the 2013-2014 National Health and Nutrition Examination Survey (NHANES). Grip strength (kg) was measured in both hands using a handgrip dynamometer and the largest reading across all trials served as the participant's score. HRQOL was assessed by a single question asking participants to rate their general health. Additionally, measures of body mass index (BMI), waist circumference (WC), moderate-to-vigorous physical activity (PA) (MVPA), TV time, sedentary time, and smoking were assessed. Multiple linear regression was used to model the relationship between HRQOL and grip strength while controlling for confounding variables.
Results: Grip strength decreased proportionately in women with increasing age (p<.001). Conversely, grip strength increased proportionately in women with increasing BMI (p<.001). In the fully adjusted model, women with good HRQOL had greater grip strength (*slope*=2.04 kg, *SE*=0.26, p<.001) than their poor HRQOL counterparts. Additionally, HRQOL was significantly related to grip strength in women who were current smokers but not in those who were not current smokers.
Conclusion: Results from this study indicate that grip strength and HRQOL are related in U.S. women. Furthermore, the grip strength and HRQOL relationship appears to remain in women who are current smokers.

Keywords: muscular fitness, health-related quality of life (HRQOL), women's health, epidemiology, NHANES

Introduction
Muscular fitness is a trait that considers both muscular strength and muscular endurance and relates to many health outcomes [1]. In studies involving women, muscular fitness has shown to be related to cardiovascular disease [2-4], cancer [5], metabolic syndrome [6, 7], depression [8, 9], falls [10], cognitive function [11, 12], and obesity [13]. Health-related quality of life (HRQOL) is an outcome measure of growing interest and is generally considered an important indicator of the impact a person's health has on their quality of life [14]. Studies have investigated the relationship between muscular strength and HRQOL using both cross-sectional [15, 16] and longitudinal [17, 18] designs. However, little evidence exists on this relationship in a representative sample of U.S. women. Therefore, the purpose of this study was to examine the relationship between grip strength and HRQOL among U.S. women. A secondary purpose was to examine the extent to which physical activity (PA), obesity, and smoking moderate the grip strength and HRQOL relationship.

Methods
Study design
Data for this research came from females 20+ years of age participating in the 2013-2014 National Health and Nutrition Examination Survey (NHANES) [19]. NHANES is a continuous survey designed to assess health behavior, health status, and nutrition of noninstitutionalized civilian residents of the U.S. NHANES collects data on individuals using personal interviews, standardized physical examinations, and laboratory tests. The current study used data only from personal interviews and physical examinations. The sample in the current study consisted of women with complete grip strength and HRQOL data.

Variables utilized
The dependent variable in this study was grip strength. The main independent variable was HRQOL. Moderating variables were binary variables indicating obesity status, meeting PA guidelines status, and current smoking status. Other variables used in this study were body mass index (BMI), waist circumference (WC), moderate-to-vigorous PA (MVPA), TV time, sedentary time, age, race, marital/partner status, income, and education.

Assessment of Grip Strength and HRQOL
HRQOL was assessed by a single question asking participants to rate their general health [20]. In this study, women rating their health as "good", "very good", or "excellent" were considered to have good HRQOL whereas those rating it "fair" or "poor" were considered to have poor HRQOL. Grip strength (kg) was measured in both hands using a handgrip dynamometer administered by a trained examiner [21]. After a submaximal practice trial and grip adjustment, participants squeezed the dynamometer as hard as possible with a randomly selected hand while in the

standing position. The test was then completed with the other hand for a total of three trials on each hand. The largest dynamometer reading across all trials served as the grip strength score in this study.

Assessment of PA variables

A continuous PA variable was computed from constructed variables of minutes of moderate physical activity (MPA) per week and minutes of vigorous physical activity (VPA) per week [22]. VPA was assessed from the responses to two questions. The first question asked respondents how many days they participated in vigorous intensity sports, fitness, or recreational activities. The second question asked respondents how much time they spend doing vigorous-intensity activity on a typical day. Multiplying days with minutes yielded minutes of VPA per week. The same two questions were asked regarding moderate-intensity activities to assess MPA per week. These two physical activity variables were then used to compute minutes of MVPA per week. A second PA variable was computed from MVPA which consisted of two discrete PA groups: (1) < 150 minutes of MVPA and (2) 150+ minutes of MVPA. TV time was assessed from a survey question asking participants how many hours per day they sat and watched TV or videos during the past 30 days [22]. For this study, two discrete TV time groups were formed: (1) < 5 hours and (2) 5+ hours. Sedentary time was assessed from a question asking participants how much time they usually spend sitting in a typical day [22]. For this study, sedentary time was converted to quartiles, where the first quartile contained the least sedentary individuals and the last quartile contained the most sedentary.

Assessment of body composition variables

Using WC, participants were categorized into two discrete groups: 1) obese (WC: > 88 cm) and non-obese (WC: ≤ 88 cm). The categorization of WC was used as the obese status variable. Using BMI (kg/m^2), participants were categorized into one of four discrete groups: 1) underweight (BMI: < 18.5), normal weight (BMI: 18.5 to 24.9), overweight (BMI: 25.0 to 29.9), and obese (BMI: 30+). Measurements for both BMI (height and weight) and WC were collected by trained NHANES health professionals during a medical examination [23].

Other variables

A smoking status variable was constructed from a question asking participants if they now smoke cigarettes [24]. Those responding "yes, every day" or "yes, some days" were considered current smokers and those responding "no, not at all" were considered non-current smokers. Demographic variables used in this study were age (20-24 yr, 25-34 yr, 35-44 yr, 45-54 yr, 55-64 yr, 65+ yr), race/ethnicity (White, Black, Hispanic, Other), household income ($0-$19.999, $20,000-$44,999, $45,000-$64,999, $65,000-$74,999, $75,000+), education (no high school diploma, high school diploma, some college, 4-year college degree), and marital/partner status (living with a spouse/partner, not living with spouse/partner).

Statistical analyses

Descriptive statistics were computed on grip strength values across HRQOL groups with associated independent *t*-tests. Tests of linear trend in grip strength were conducted across ordinal variables and analysis of variance (ANOVA) tests conducted across nominal variables. Follow-up mean comparisons with Tukey-Kramer adjustments were made across all groups when the omnibus test was significant and group levels were greater than 2. Multiple linear regression analysis of grip strength regressed on HRQOL was conducted at three different levels. First, regression models were age-adjusted (Model I). Second, regression models were adjusted for age, race/ethnicity, marital/partner status, income, and education (Model II). Lastly, regression models were adjusted for age, race/ethnicity, marital/partner status, income, education, MVPA, sedentary time, and BMI (Model III). Additionally, three other sets of regression models were run to examine moderator effects (obese, PA, and smoking). All analyses were performed using the survey procedures of SAS version 9.4 [25-27]. The CORRPLOT package of R was used for graphics [28]. All *p*-values were reported as 2-sided and statistical significance was defined as *p*-values < 0.05.

Results

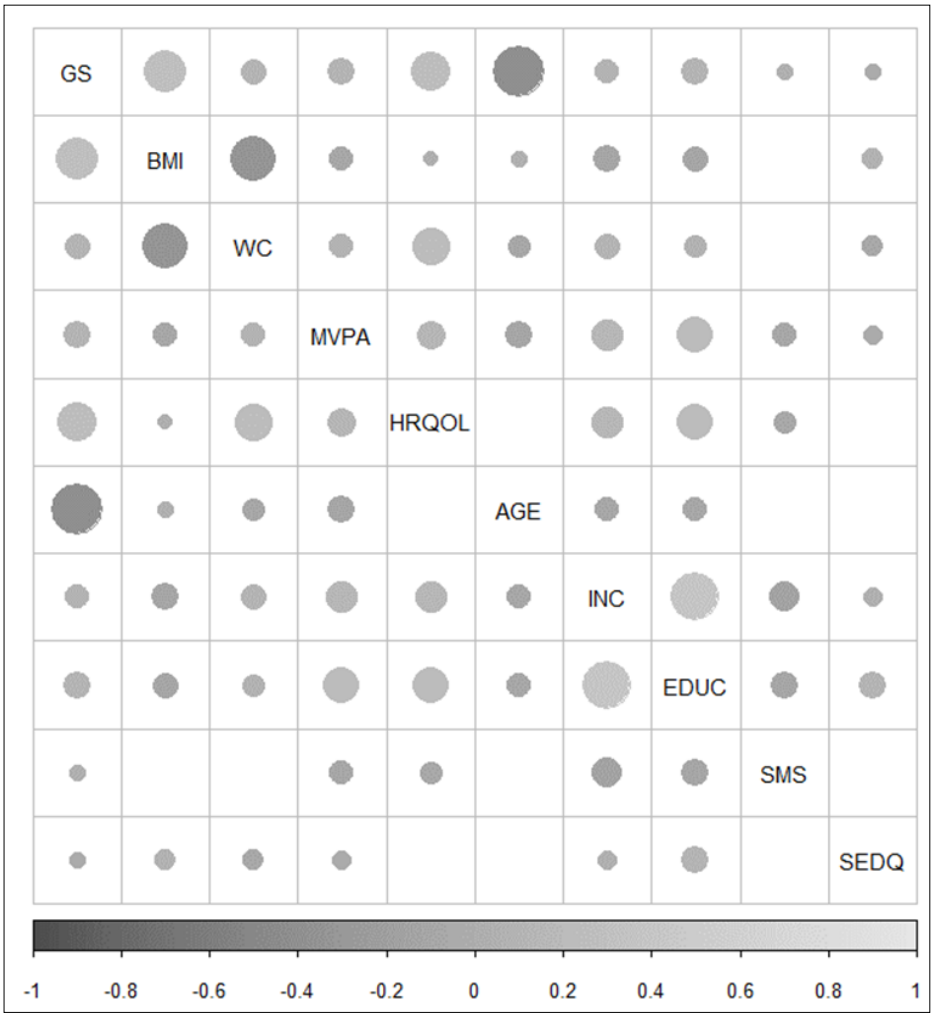
Table 1 contains descriptive statistics on grip strength values by HRQOL across demographic groups. Overall, women reporting poor HRQOL had significantly lower grip strength than women reporting good HRQOL, *Mean* (*SE*): 27.4(0.26) vs. 29.9(0.17), $p<.001$. Additionally, a significant ($ps<.001$) linear trend in grip strength across age groups was seen in both HRQOL groups, with strength decreasing as age increased. Furthermore, for women 35 years of age and older, grip strength was significantly ($ps<.05$) greater if reporting good HRQOL as compared to poor HRQOL. Race/ethnicity was a significant factor related to grip strength, however, only in those reporting good HRQOL. Black women reporting good HRQOL had significantly ($ps_{adjusted}<.05$) greater strength than all other race/ethnicity groups. Finally, women with at least some college education had significantly ($ps_{adjusted}<.05$) greater grip strength than women without a high school diploma.

Table 2 contains descriptive statistics on grip strength values by HRQOL across health characteristic groups. All health subgroups saw significantly ($ps<.05$) greater grip strength among women reporting good HRQOL as compared to those reporting poor HRQOL. Additionally, a significant ($ps<.001$) linear trend in grip strength across BMI groups was seen in both HRQOL groups, with strength increasing as BMI increased. Lastly, a modest yet significant ($ps<.001$) linear trend in grip strength across sedentary time quartiles was seen in both HRQOL groups, with strength decreasing as sedentary time increased.

Figure 1 contains a correlation matrix plot of all study variables, where the size of the circles represents the strength of correlation and the shade (e.g., darker) represents the direction (e.g., negative). All correlations (circles) shown in figure 1 were significant ($ps<.05$) with blank cells representing a non-significant relationship. The most noteworthy result from this matrix showed that grip strength was significantly ($ps<.05$) related to all study variables. Furthermore, the largest grip strength correlations were seen with BMI, HRQOL, and age.

Table 3 displays results from the multiple linear regression analysis of grip strength regressed on HRQOL. In the age-adjusted model, women with good HRQOL had greater grip strength (*slope*=1.83 kg, *SE*=0.24, $p<.001$) than their poor HRQOL counterparts. Adjusting for demographic

(*slope*=1.58 kg, *SE*=0.32, *p*<.001) and health (*slope*=2.04 kg, *SE*=0.26, *p*<.001) characteristics did not change the significance of the relationship. Furthermore, analyses across moderator variables showed a similar trend, with exception for smoking status. That is, in fully adjusted models, HRQOL was significantly related to grip strength in women who were current smokers (*slope*=1.72 kg, *SE*=0.46, *p*=.002) but not in those who were not current smokers (*slope*=0.44 kg, *SE*=0.88, *p*=.623).



Note: GS is grip strength. BMI is body mass index. WC is waist circumference. MVPA is moderate-to-vigorous physical activity. HRQOL is health-related quality of life. AGE is age. INC is household income. EDUC is education level. SMS is smoking status. SEDQ is sedentary time quartile. All cells with circles indicate a significant (p<.05) correlation coefficient.

Fig 1: Correlation matrix of study variables.

Table 1: Descriptive values of grip strength by HRQOL across demographic characteristics, U.S. women 20+ years of age 2013-2014.

	Good HRQOL			Poor HRQOL			
Characteristic	**Mean**	**SE**	**t**	**Mean**	**SE**	**t**	**P**
Overall	29.92	0.17		27.44	0.26		<.001
Age group (yr)							
20-24	31.42	0.55	a	31.70	0.97	a	.771
25-34	32.17	0.31	b	32.09	0.71	b	.923
35-44	32.40	0.30	c	29.80	0.56	c	.002
45-54	31.51	0.34	d	29.21	0.55	d	.007
55-64	28.56	0.32	a,b,c,d	26.00	0.80	a, b, c	.012
65+	24.45	0.33	a,b,c,d	21.43	0.54	a,b,c,d	<.001
p for trend			<.001			<.001	
Race/Ethnicity							
White	29.58	0.20	a	26.57	0.37	a,b	<.001
Black	33.23	0.39	a,b,c	29.79	0.76	a,c	.001
Hispanic	29.84	0.31	b	28.06	0.30	b	<.001
Other	28.45	0.43	c	27.02	0.88	c	.169
p for overall diff			<.001			.107	

Income (US $)							
0-19,999	29.01	0.50		26.20	0.64		<.001
20,000-44,999	29.22	0.31		28.37	0.50		.127
45,000-64,999	31.00	0.47		28.61	0.86		.042
65,000-74,999	30.99	0.71		28.81	1.50		.148
75,000+	30.13	0.21		26.71	0.96		.003
p for trend			.056			.054	
Education							
No high school diploma	28.46	0.36	a,b	27.23	0.81		.114
High school diploma	29.51	0.35		27.54	0.67		.017
Some college	30.57	0.26	a	28.11	0.60		.003
4-year college degree	29.91	0.22	b	25.21	1.30		.004
p for trend			<.001			.374	
Living with spouse/partner							
Yes	30.18	0.19		27.79	0.26		<.001
No	29.53	0.32		27.06	0.36		<.001
p for overall diff			.111			.059	

Note: Grip strength values are in kilograms (kg). p-values in bold are significant at the .05 level. t column represents tests of within group differences with Tukey-Kramer adjustment where groups with same letter represent a significant difference.

Table 2: Descriptive values of grip strength by HRQOL across health characteristics, U.S. women 20+ years of age 2013-2014.

Characteristic		**Good HRQOL**			**Poor HRQOL**			***p***
		Mean	***SE***	***t***	***Mean***	***SE***	***t***	
BMI group	Underweight	26.54	1.28	a	22.03	3.03		<.001
	Normal weight	28.94	0.30	b	24.91	0.75	a	<.001
	Overweight	29.79	0.29	c	26.64	0.81		.002
	Obese	31.19	0.33	a,b,c	28.69	0.39	a	<.001
p for trend				<.001			<.001	
WC group	Obese	30.41	0.21		28.10	0.24		<.001
	Not obese	29.30	0.25		25.60	0.74		<.001
p for diff				.004			.005	
Met PA Guidelines	No	29.61	0.25		27.36	0.31		<.001
	Yes	30.40	0.18		27.94	0.74		<.001
p for diff				.002			.521	
TV time (per day)	< 5 hours	30.08	0.16		28.10	0.27		<.001
	5+ hours	28.70	0.72		25.80	0.47		.001
p for diff				.076			<.001	
Sedentary time (quartiles)	Q1 (least sedentary)	30.56	0.23	a	29.14	0.42	a	.006
	Q2	29.60	0.26	a	27.84	0.52		.007
	Q3	29.84	0.32		25.74	0.98	a	.002
	Q4 (most sedentary)	29.69	0.32		27.45	0.70		.003
p for trend				.010			.004	
Current smoker	No	28.94	0.43		26.93	0.76		<.001
	Yes	31.24	0.34		28.62	0.33		<.001
	p for diff			.003			.021	

Table 3: Multiple linear regression analysis of grip strength regressed on HRQOL, U.S. women 20+ years of age 2013-2014.

Characteristic		**Model I**			**Model II**			**Model III**		
		Estimate	***SE***	***p***	***Estimate***	***SE***	***p***	***Estimate***	***SE***	***p***
Overall	Poor HRQOL	reference			reference			reference		
	Good HRQOL	1.83	0.24	<.001	1.58	0.32	<.001	2.04	0.26	<.001
Did meet PA Guidelines	Poor HRQOL	reference			reference			reference		
	Good HRQOL	2.00	0.50	.001	1.59	0.57	.013	2.27	0.55	<.001
Did not meet PA Guidelines	Poor HRQOL	reference			reference			reference		
	Good HRQOL	1.74	0.29	<.001	1.51	0.37	<.001	1.89	0.33	<.001
Obese	Poor HRQOL	reference			reference			reference		
	Good HRQOL	2.03	0.26	<.001	1.80	0.35	<.001	1.59	0.32	<.001
Non-obese	Poor HRQOL	reference			reference			reference		
	Good HRQOL	3.02	0.72	<.001	2.15	0.81	.017	2.05	0.85	.029
Is a current smoker	Poor HRQOL	reference			reference			reference		
	Good HRQOL	1.90	0.46	<.001	1.69	0.49	.004	1.72	0.46	.002
Is not a current smoker	Poor HRQOL	reference			reference			reference		
	Good HRQOL	0.95	0.74	.220	0.65	0.85	.455	0.44	0.88	.623

Discussion

The primary purpose of this study was to examine the relationship between muscular fitness (grip strength) and HRQOL in a representative sample of U.S. women. Results

support HRQOL as a predictor of grip strength in women, with better HRQOL indicative of greater muscular strength. Furthermore, this relationship endured after rigorous adjustment for possible confounding variables. Therefore, this study presents evidence that surpasses previously mentioned studies [15-18] in that it supports the muscular fitness and HRQOL relationship among all non-institutionalized U.S. women.

A secondary purpose of this study was to examine the moderating effects of PA, obesity, and smoking status on the grip strength and HRQOL relationship. This portion of the study showed conflicting results. For example, analyses by both PA and obese factors, indicated no differences in the muscular strength and HRQOL relationship. That is, HRQOL was a statistical predictor of strength regardless of PA or obesity status. However, analyses across smoking status indicated a difference in this relationship. Namely, among women who currently smoked, HRQOL was a statistical predictor of muscular strength. Conversely, among women who did not currently smoke, the HRQOL and muscular strength relationship was diminished to a non-significant level. For the former significant scenario, these findings may in part be explained by the HRQOL construct itself. That is, among smokers, there are likely women who maintain an otherwise healthy lifestyle and who rate their overall HRQOL as good and consequently have adequate muscular fitness. On the other hand, among smokers, there are likely women who maintain an unhealthy lifestyle and rate their general HRQOL as poor and consequently have inadequate muscular fitness. Said differently, HRQOL as a construct may be able to detect group differences in health status with more specificity in a smoking population than in a healthier population [29, 30]. Therefore, these results additionally stipulate that HRQOL may be a valid predictor of muscular fitness in relatively unhealthy populations, such as women who smoke.

The following strengths of this research should be discussed. One strength of this study was its use of an objective measure of muscular fitness. The use of a dynamometer-derived grip strength measure added strong measurement properties to the assessment of the study's dependent variable [31, 32]. Another strength of this study was its use of a nationally representative sample of women. NHANES data represent all noninstitutionalized civilian U.S. individuals residing in the 50 states and District of Columbia [33]. Therefore, results from this study can be generalized to all noninstitutionalized U.S. adult females 20+ years of age.

The limitations of this research should also be discussed. The most serious limitation in this study is the cross-sectional nature of the NHANES study design. It should be stated that evidence from cross-sectional data do not provide cause-and-effect evidence. That is, results from this study do not support the notion that HRQOL causes muscular strength. Results from this study should be considered as correlational only. Another limitation of this study was the self-report assessment of HRQOL and PA. More specifically, self-report questionnaires have certain biases over more objective means of measurement. Given this bias, the HRQOL item used in this study has shown to have adequate psychometric properties [34, 35]. As well, the items used to assess PA in this study also have adequate psychometric properties supporting their use in this population [36, 37].

Conclusions

Results from this study indicate that muscular fitness and HRQOL are related in U.S. women. The muscular fitness and HRQOL relationship appears to remain in women regardless if they meet PA guidelines and regardless of their obesity status. However, the muscular fitness and HRQOL relationship appears to exist in women who are current smokers and not in women who are not current smokers. Health promotion efforts directed toward improving HRQOL may also find benefits of improved muscular fitness in U.S. women.

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