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Fitness and Adiposity as Predictors of Functional Limitation in Adults

Andréa L. Maslow, Anna E. Price, Xuemei Sui, Duck-chul Lee, Ikka Vuori, and Steven N. Blair

Background: This study examined the associations of body mass index (BMI), waist circumference (WC), and cardiorespiratory fitness (CRF) with incident functional limitation (IFL) in adults. ***Methods:*** Patients (n = 2400), 30+ years [mean age, 45.2 (SD, 8.3); 12% women], completed a baseline health examination during 1979 to 1995. CRF was quantified by age-and sex-specific thirds for maximal treadmill exercise test duration. Adiposity was assessed by BMI and WC (grouped for analysis according to clinical guidelines). Incident IFL was identified from mail-back surveys during 1995, 1999, and 2004. ***Results:*** After adjusting for potential confounders and either BMI or WC, CRF was inversely related to IFL (P trend < .001). The association between BMI and IFL was significant after adjusting for all confounders (P trend = .002), but not after additional adjustment for CRF (P trend = .23). After controlling for all confounders and CRF, high WC was associated with greater odds of IFL in those aged 30 to 49; normal WC was associated with greater odds of IFL in those aged 50+. ***Conclusions:*** CRF was a significant predictor of IFL in middle aged and older adults, independent of overall or abdominal adiposity. Clinicians should consider the importance of preserving functional capacity by recommending regular physical activity for normal-weight and overweight individuals.

Keywords: waist circumference, physical activity, body mass index, older adults, longitudinal study

Functional limitation, or the inability to carry out major tasks of daily living,[1] is a significant predictor of health related quality of life, morbidity, and mortality.[2] According to data from the 2006 National Health Interview Survey, 3.9 million adults have limitation in activities of daily living (ADL), such as eating, dressing, or bathing, and 7.8 million have limitation in instrumental activities of daily living (IADL), such as household chores and shopping.[3] Functional limitation is a significant public health issue as it can lead to high economic, societal, and personal costs.[4] To reduce the prevalence of persons experiencing limitation in activity, it is important to identify factors that contribute to the development of functional limitation over time.

Previously our group found that persons with moderate to high levels of cardiorespiratory fitness (CRF) are less likely to develop subsequent functional limitation than those with low CRF.[1] Other research suggests obesity may increase the risk of functional limitation in middle aged and older adults.[5–12] While the above studies provide evidence that excess body weight and low fitness are associated with an increased risk of functional limitation, it is unclear whether these associations are independent of one another.

In addition, many of the studies examining the association between adiposity and functional limitation have only used body mass index (BMI) as a measure of adiposity.[7–10,12] Fewer studies have examined the relationship between waist circumference (WC), as an indication of visceral adiposity, and incident functional limitation.[5,13,14]

Koster and colleagues[14] recently examined the independent and joint associations of adiposity (BMI, percent body fat, and WC) and physical activity on the onset of mobility limitation in black and white older adults. Findings revealed that high adiposity and low-self reported physical activity predicted the onset of mobility limitation. To the best of our knowledge, no study has examined the independent and joint associations among CRF, adiposity (BMI and WC), and incident functional limitation in middle-aged and older adults. Therefore, the objectives of this study are to 1) examine the independent associations of BMI, WC, and CRF with development of functional limitation and 2) to examine the joint associations among BMI, CRF, and functional limitation and WC, CRF, and functional limitation in a cohort of middle aged and older adults enrolled in the Aerobics Center Longitudinal Study (ACLS). Our study builds on previous research by including CRF, an objective reproducible measure that reflects recent

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physical activity habits, disease status, and genetics.[15] In addition, many studies examining the predictors of functional limitation have examined these relationships solely in older adults.[8,10,11,13,16] Our study examined the relationships between CRF, adiposity, and incident functional limitation in both middle aged and older adults to provide evidence regarding the relationships between these factors at various stages in the lifespan.

Methods

Study Population and Design

The ACLS is an ongoing prospective study which examines the association of physical activity and physical fitness to health outcomes in patients examined at the Cooper Clinic in Dallas, TX since 1970. The current study consists of 2400 men and women (mean age: 45 ± 8; range: 30–77 years) who completed a baseline clinical examination between 1979 and 1995. Inclusion criteria for the current analysis required participants to have a maximal treadmill exercise test at baseline, during which they must have achieved at least 85% of their age-predicted maximal heart rate [220 – age (years)], returned the 1995 follow-up mail-back survey to exclude those with current functional limitation, and returned at least 1 additional mail-back health survey from 1999 or 2004 to ascertain incident functional limitation. We excluded those under age 30, those with baseline heart attack, stroke, diabetes, cancer, arthritis or hypertension and participants with any missing data on adjusted variables (see statistical analysis). In addition, those participants reporting a functional limitation on the 1995 mail-back survey were excluded from the study. The majority of study participants was white, well-educated, from middle to upper socioeconomic strata, and employed in, or retired from, professional or executive positions. All participants provided written informed consent to participate in the follow-up study, and the Cooper Institute Institutional Review Board approved the study annually.

Baseline Examination

Before the medical examination, the participants fasted for 12 hours and were asked not to smoke on the day of examination. The medical examination included: a thorough physical exam (each physician examines only 3 to 4 patients/day); anthropometrics; blood pressure; blood chemistry tests; maximal treadmill exercise test; and a questionnaire of personal and family medical history, demographic characteristics, and health habits. All procedures were administered by trained technicians who followed standardized protocols. Height and weight were measured using a stadiometer and standard physician's scale. WC was measured level with the umbilicus. Resting blood pressure was recorded as the first and fifth Korotkof sounds by auscultatory methods. Serum samples were analyzed for lipids and glucose using standardized automated bioassays. Information on smoking habits (current, former, or never smoker) and alcohol intake (<5/≥5 drinks per week) were obtained from a standardized questionnaire.

CRF was assessed by a maximal treadmill test using a modified Balke protocol as previously described.[17,18] CRF was categorized into age- and sex-specific thirds. To obtain the age- and sex-specific CRF thirds, CRF (minutes on treadmill) was divided into thirds (low, middle, and high fitness) within 4 age groups (30–39, 40–49, 50–59, and 60+ yr) within gender groups. Next, the age- and sex-specific thirds were combined across age groups and genders with high fitness (the highest third) as the referent level. In primary analyses, CRF was defined categorically as low, middle, and high (reference group). In secondary analyses we grouped fitness into a binary variable, physically unfit (the lowest 20%) compared with physically fit (remaining 80%, referent group) to preserve sample size for tests of joint association. This approach is a standardized method in the ACLS; low fitness, defined as the lowest 20% of the CRF distribution, is an independent predictor of morbidity and mortality.[19–21]

Adiposity exposure groups were based on standard clinical definitions for BMI (normal weight, 18.5 to 24.9 kg/m^2; overweight, 25.0 to 29.9 kg/m^2; obese, ≥30.0 kg/m^2) and WC (normal, <88.0 cm for women and <102.0 cm for men; indicating abdominal obesity, ≥88.0 cm for women and ≥102.0 cm for men).[22] For primary analyses, BMI, was defined categorically as normal weight (reference group), overweight, obese; WC, was defined categorically as normal (reference group) and high. In secondary analyses, we grouped BMI into a binary variable, normal weight and overweight (overweight and obese categories combined) to preserve sample size for tests of joint association.

Ascertainment of Incidence of Functional Limitation

The incidence of functional limitation was ascertained from responses to mail-back health surveys in 1995, 1999, and 2004. The 1995 survey served as the baseline; all participants reporting a functional limitation in 1995 were excluded from the study. The 1999 and 2004 surveys were then used to prospectively identify incident functional limitation. The mean follow-up time from baseline examination to the mail-back survey was 16.13 years. The overall response rate across surveys in the ACLS is about 65%.[23] Although this response rate is relatively low, it is consistent with recent experiences in other follow-up studies.[24,25] Nonresponse bias is a concern in epidemiological surveillance; however, this issue has been investigated in the ACLS and found both responders and nonresponders were equally healthy at entry.[26] Baseline health histories and clinical measures were similar between responders and nonresponders and between early and late responders.

The functional status section of the questionnaire contained questions regarding the participants' ability to perform recreational activities (ie, bicycling, fishing), household activities (ie, cooking, cleaning), daily activities (ie, bending, twisting), and personal care activities (ie, bathing, dressing). Respondents were asked to report the degree of difficulty they had performing each category of tasks. Possible responses were: no difficulty; some difficulty; much difficulty; and cannot do. Participants were classified as having a functional limitation if they reported having any difficulty with at least 1 activity or not being able to perform at least 1 activity.[1] The questions on functional status were developed by an expert panel who had reviewed functional and mobility scales.[1]

Participants were also asked to report the ascertainment of certain diseases and the year of diagnosis for any incident disease conditions. Any new diseases or conditions diagnosed after the baseline examination were coded as positive in a dichotomous variable called new disease at follow-up.

Statistical Analysis

Descriptive statistics were computed for each variable. Pearson correlation analyses were used to examine the strength of the association among BMI, WC, and CRF (treadmill exercise duration in minutes). Logistic regression analyses were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of functional limitation events according to BMI, WC, and CRF categories. Indicator variables (did not respond/responded) for each of the 2 survey periods were constructed to account for differences in survey response frequency to reduce the influence of ascertainment bias. For the total population (n = 2400), separate multivariable adjusted models for BMI, WC, and CRF first controlled for the potential confounding effects of gender, baseline age, year of the baseline examination, and survey response indicator variables (yes/no) (Models 1, 4, & 7). Then, separate multivariable adjusted models for BMI, WC, and CRF additionally controlled for smoking habits (current/former/never), alcohol intake (≥5 drinks/wk or not), and incident disease conditions (myocardial infarction, stroke, hypertension, arthritis, cancer, diabetes) (Models 2, 5, & 8). For both BMI and WC, a third multivariable adjusted model additionally controlled for CRF (Models 3 & 6). For CRF, 2 separate multivariable adjusted models additionally controlled for BMI and WC (Models 9 & 10).

To examine potential effect modification, additional stratum specific Logistic-regression analyses for BMI, WC, and CRF were performed according to gender and baseline age group (30–40 years, 40–50 years, 50+ years) after adjusting for all potential confounders.

To examine the joint associations, separate Logistic-regression ORs were calculated for the joint effects between BMI and CRF and between WC and CRF after adjusting for all potential confounders. Tests of linear trends across exposure categories were computed using ordinal scoring. All P values are 2 sided and all significant results had a P value below 0.05.

Results

Participant Characteristics

The mean age of participants at baseline was 45.2 (SD, 8.3) years, and 12% of the study sample was female. Participants' characteristics are shown by BMI, WC, and CRF in Table 1. In total, there were 1,164 cases of incident functional limitation. There were 703, 405, and 56 cases of functional limitation in the normal weight, overweight, and obese BMI exposure groups; 1067 and 97 cases of functional limitation in the normal and high WC exposure groups; and 353, 429, and 383 cases of functional limitation in the low, middle, and high CRF group, respectively. Both measures of adiposity and treadmill exercise duration were significantly correlated. Specifically, there were significant negative correlations between BMI and treadmill exercise duration (r = –0.23, $P < .001$) and WC and treadmill exercise duration (r = –0.13, $P < .001$) and a significant positive relationship between BMI and WC (r = .81, $P < .001$).

Table 2 presents the ORs and CIs for BMI, WC, and CRF exposure categories and functional limitation. After adjusting for gender and age at baseline, examination year, and survey response pattern, the ORs for functional limitation across BMI categories were 1.35 (95% CI, 1.12 to 1.62) for overweight, and 2.01 (95% CI, 1.30 to 3.13) for obese, compared with normal weight (Model 1). Similar results were observed after additional adjustment for smoking status, alcohol intake, and new health conditions, with ORs for overweight and obese groups being slightly attenuated (Model 2). When the model was additionally adjusted for CRF, the odds of overweight and obese groups developing functional limitation were no longer significantly different than that of the normal weight group (Model 3).

After adjusting for gender and age at baseline, examination year, and survey response pattern, the OR for functional limitation among those with a high WC was 1.85 (95% CI, 1.31 to 2.62) compared with those with a normal WC (Model 4). After additional adjustment for smoking status, alcohol intake, and new health conditions, the OR was slightly attenuated (Model 5). Once CRF was added to the model, the OR for functional limitation among those with high WC was no longer significantly greater than the odds for those with normal WC (Model 6).

We also examined the association between CRF and functional limitation. After adjusting for gender and age at baseline, examination year, and survey response pattern, the ORs for functional limitation across thirds of CRF were 1.59 (95% CI, 1.30 to 1.93) for middle CRF and 2.13 (95% CI, 1.69 to 2.68) for low CRF, compared with high CRF (Model 7). After additional adjustment for smoking status, alcohol intake, and new health conditions, the ORs of functional limitation across thirds of CRF were 1.55 (95% CI, 1.27 to 1.89) for middle CRF

Table 1 Participant Characteristics at Baseline by BMI Categories, WC Categories, and Thirds of CRF

		BMI			WC		CRF		
	Total	Normal	OW	Obese	Normal	High	Low	Middle	High
Characteristics	(n = 2400)	(n = 1508)	(n = 796)	(n = 96)	(n = 2242)	(n = 158)	(n = 588)	(n = 847)	(n = 965)
Sex*, No. (%)									
Women	293 (12.2)	264 (17.5)	29 (3.6)	1 (1.0)	286 (12.8)	7 (4.4)	184 (31.3)	80 (9.4)	29 (3.0)
Men	2107 (87.8)	1245 (82.6)	767 (96.4)	95 (99.0)	1956 (87.2)	151 (95.6)	404 (68.7)	767 (90.6)	936 (97.0)
Age*, mean (SD)	45.2 (8.3)	44.8 (8.4)	45.9 (8.2)	45.3 (7.7)	45.0 (8.3)	47.1 (8.9)	45.5 (8.5)	45.3 (8.3)	44.9 (8.3)
Age group*, No. (%)									
30–39	649 (27.0)	444 (29.4)	181 (22.7)	24 (25.0	617 (27.5)	32 (20.3)	160 (27.2)	237 (28.0)	252 (26.1)
40–49	1052 (43.8)	632 (41.9)	374 (47.0)	46 (47.9)	982 (43.8)	70 (44.3)	262 (44.6)	362 (42.7)	428 (44.4)
50–59	566 (23.6)	360 (23.9)	183 (23.0	23 (24.0)	525 (23.4)	41 (25.9)	138 (23.5)	196 (23.1)	232 (24.0)
60+	133 (5.5)	72 (4.8)	58 (7.3)	3 (3.1)	118 (5.3)	15 (9.5)	28 (4.8)	52 (6.1)	53 (5.5)
Alcohol*, No. (%)									
≥5 drinks/wk	640 (26.7)	393 (26.1)	221 (27.8)	26 (27.1)	598 (26.7)	42 (26.6)	110 (18.7)	226 (26.7)	304 (31.5)
Smoking*, No. (%)									
Never	1841 (76.7)	1199 (79.5)	580 (72.8)	62 (64.6)	1732 (77.3)	109 (69.0)	439 (74.7)	628 (74.1)	774 (80.2)
Current	236 (9.8)	137 (9.1)	81 (10.2)	18 (18.8)	214 (9.5)	22 (13.9)	86 (14.6)	96 (11.3)	54 (5.6)
Former	323 (13.5)	172 (11.4)	135 (17.0)	16 (16.7)	296 (13.2)	27 (17.1)	63 (10.7)	123 (14.5)	137 (14.2)
		BMI			WC		CRF		
	Total	Normal	OW	Obese	Normal	High	Low	Middle	High
Characteristics	(n = 2400)	(n = 1508)	(n = 796)	(n = 96)	(n = 2242)	(n = 158)	(n = 588)	(n = 847)	(n = 965)
New disease†, No. (%)									
DM	54 (2.3)	19 (1.3)	24 (3.0)	11 (11.5)	40 (1.8)	14 (8.9)	24 (4.1)	21 (2.5)	9 (0.9)
MI	65 (2.7)	38 (2.5)	25 (3.1)	2 (2.1)	61 (2.7)	4 (2.5)	13 (2.2)	34 (4.0)	18 (1.9)
Leg Arth.	186 (7.8)	111 (7.4)	63 (7.9)	12 (12.5)	165 (7.4)	21(13.3)	55 (9.4)	60 (7.1)	71 (7.3)
HBP	408 (17.0)	216 (14.3)	169 (21.2)	23 (24.0)	368 (16.4)	40 (25.3)	121 (20.6)	142 (16.8)	145 (15.0)
Cancer	189 (7.9)	115 (7.6)	69 (8.7)	5 (5.2)	179 (8.0)	10 (6.3)	50 (8.5)	64 (7.5)	75 (7.9)
Stroke	38 (1.6)	24 (1.6)	12 (1.5)	2 (2.1)	34 (1.5)	4 (2.5)	10 (1.7)	16 (1.9)	12 (1.2)
Fx limitation†, No. (%)									
Yes	1164 (49.5)	703 (46.6)	405 (50.9)	56 (58.8)	1067 (47.6)	97 (61.4)	353 (60.0)	429 (50.6)	383 (39.7)

Abbreviations: No., number; SD, standard deviation; CRF, cardiorespiratory fitness; DM, diabetes mellitus; MI, myocardial infarction; Leg Arth, leg arthritis; HBP, high blood pressure; Fx, functional; BMI, Body Mass Index; WC, waist circumference; OW, overweight.

* Assessed at baseline examination.

† Assessed using data from baseline examinations and mail-back surveys, this shows the number of participants with functional limitation for each BMI, WC, and CRF group.

Table 2 Odds Ratios and Confidence Intervals for Functional Limitation by BMI, WC, and CRF

	Baseline BMI			
	Normal	**Overweight**	**Obese**	***P* for linear trend**
Model 1[a], OR (95%CI)	1.0	1.35 (1.12,1.62)	2.01 (1.30,3.13)	<.001
Model 2[b], OR (95%CI)	1.0	1.26 (1.04,1.53)	1.70 (1.08,2.68)	.002
Model 3[c], OR (95%CI)	1.0	1.09 (0.90,1.33)	1.29 (0.80,2.06)	.227
	Baseline WC			
	Normal	**High**		***P* for linear trend**
Model 4[a], OR (95%CI)	1.0	1.85 (1.31,2.62)		<.001
Model 5[b], OR (95%CI)	1.0	1.62 (1.14,2.31)		.008
Model 6[c], OR (95%CI)	1.0	1.28 (0.89,1.85)		.215
	Baseline CRF			
	Low	**Middle**	**High**	***P* for linear trend**
Model 7[a], OR (95%CI)	2.13 (1.69,2.68)	1.59 (1.30,1.93)	1.0	<.001
Model 8[b], OR (95%CI)	1.98 (1.57,2.52)	1.55 (1.27,1.89)	1.0	<.001
Model 9[d], OR (95%CI)	1.89 (1.47,2.43)	1.51 (1.23,1.85)	1.0	<.001
Model 10[e], OR (95%CI)	1.90 (1.49,2.43)	1.53 (1.25,1.87)	1.0	<.001

[a] Adjusted for baseline age, gender, examination year, and survey response pattern.

[b] Additionally adjusted for smoking (never, current, former) and alcohol intake (<5/≥5 drinks/wk) at baseline, and new health conditions (myocardial infarction, stroke, leg arthritis, cancer, diabetes) diagnosed after the baseline examination.

[c] Additionally adjusted for CRF.

[d] Additionally adjusted for BMI.

[e] Additionally adjusted for WC.

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, Body Mass Index; WC, waist circumference; CRF, cardiorespiratory fitness.

and 1.98 (95% CI, 1.57 to 2.52) for low CRF, compared with high fitness (Model 8). When BMI was added to the model, these results were only slightly attenuated (Model 9). Similar results were observed when WC was included in the model (Model 10).

Potential Effect Modifiers

We also examined the influence of BMI, WC, and CRF on incidence of functional limitation within strata of known functional limitation risk factors, such as age and gender, after adjusting for other potential confounders. When stratified according to age (30–40, 40–50, 50+ years) and gender, no possible effect modifiers were noted with BMI or CRF (data not shown). There was no significant interaction between gender and WC; there was a significant interaction between WC and age group. Therefore, the relationship between WC and functional limitation was examined within age strata (30–40, 40–50, 50+ years) using stratified analysis. This model was adjusted for gender and age at baseline, examination year, survey response pattern, smoking status, alcohol intake, new health conditions, and CRF.

For ages 30 to 39 years, the high WC group was 2.74 (95% CI, 1.23 to 6.11) times more likely to develop functional limitation than the normal WC group. For 40 to 49 years, the high WC group was 1.81 (95% CI, 1.02 to 3.22) times more likely to develop functional limitation than the normal WC group. Among those over 50 years of age, the high WC group was less likely (OR, 0.48; 95% CI, 0.26 to 0.89) to develop functional limitation than the normal WC group.

Joint Associations

BMI and CRF. We then examined the joint associations among BMI and CRF and functional limitation, adjusting for gender, baseline age, year of the baseline examination, smoking habits, alcohol intake, survey response pattern, and incident disease conditions. BMI was dichotomized as normal and overweight (overweight and obese groups) and fitness was dichotomized as unfit and fit to preserve sample size and numbers of functional limitation within each BMI and CRF stratum.

Figure 1 shows the ORs for the joint associations of CRF and BMI for developing functional limitation. The results show that regardless of weight status, the odds for developing functional limitation were higher for those who are unfit than those who are fit. Within those who were fit, the odds of overweight persons developing functional limitations were 1.3 (95% CI, 1.05 to 1.55) times greater than the odds for normal weight persons.

WC and CRF. Because there was a significant interaction between age group and WC exposure group, the joint association between WC and CRF and functional limitation was examined within 2 age strata: the younger

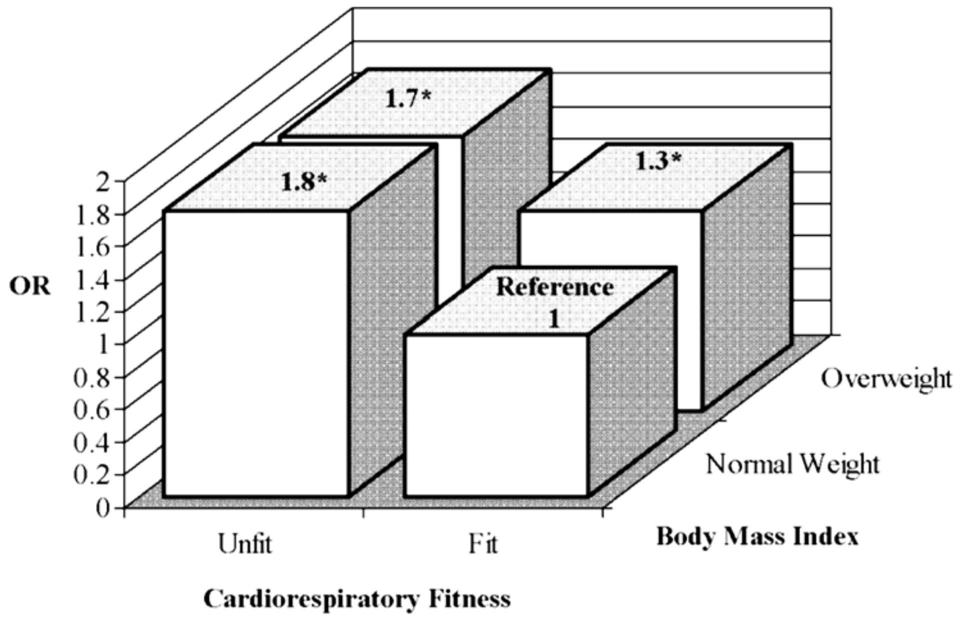

Figure 1 — Joint association of BMI and CRF for developing functional limitation. * $P < .05$. OR = Odds ratio.

group (aged 30 to 50 years) and older group (50+ years). CRF was dichotomized as unfit and fit to preserve sample size and numbers of functional limitation within each WC and CRF stratum.

The ORs for the joint association of WC and CRF and functional limitation within the younger age strata are shown in Figure 2a. Within the younger age group, a high WC significantly increased one's odds for functional limitation compared with having a normal WC. Those who were fit with a high WC had twice the odds of developing functional limitation compared with those who were fit with a normal WC. The odds of developing functional limitation among those who were unfit with a high WC were 3 times as great compared with those who were fit and had a normal WC.

The ORs for the joint association of WC and CRF and functional limitation within the older age strata are shown in Figure 2b. Within the older age group, the odds of developing functional limitation were lower for those with a high WC compared with those with a normal WC regardless of fit or unfit status. However, these differences were not statistically significant. On the other hand, among unfit persons with a normal WC, the odds of developing functional limitation were 3 times as great compared with fit persons with a normal WC.

Discussion

The objectives of this study were to examine the independent and joint associations between incident functional limitation and BMI, WC, and CRF in middle-aged and older adults. This study builds off of our group's previous work which found that persons with moderate to high levels of cardiorespiratory fitness (CRF) are less likely to develop subsequent functional limitation than those with low CRF.[1] This is the first study to examine the joint associations between functional limitation and BMI, WC, and CRF. In analyses adjusted for age, gender, examination year, and survey response pattern, BMI, WC, and CRF were all associated with incident functional limitation, with the overweight and obese exposure groups, high WC exposure group, and middle and low CRF exposure groups having significantly greater odds of functional limitation than the normal BMI, normal WC, and high CRF exposure groups, respectively. These associations were only slightly attenuated when additionally adjusting for smoking status, alcohol intake, and new health conditions. Further adjustment for CRF eliminated the significant difference between BMI and functional limitation and WC and functional limitation. However, when the CRF model was additionally adjusted for either BMI or WC, the association between CRF and functional limitation remained significant. These findings suggest CRF is a significant predictor of incident functional limitation, which is consistent with findings from our previous work.[1] This study builds on our previous work by identifying an age-WC interaction and examining the joint associations of CRF and BMI, and CRF and WC, in predicting functional limitation.

Analyses stratified by age group revealed that after adjusting for age, gender, examination year, survey response pattern, alcohol intake, smoking, new health conditions, and CRF, high WC was associated with greater odds of functional limitation in younger age groups (30–39 years, 40–49 years); however, normal WC was associated with greater odds of functional limitation in the older age group (50+ years). The presence of an

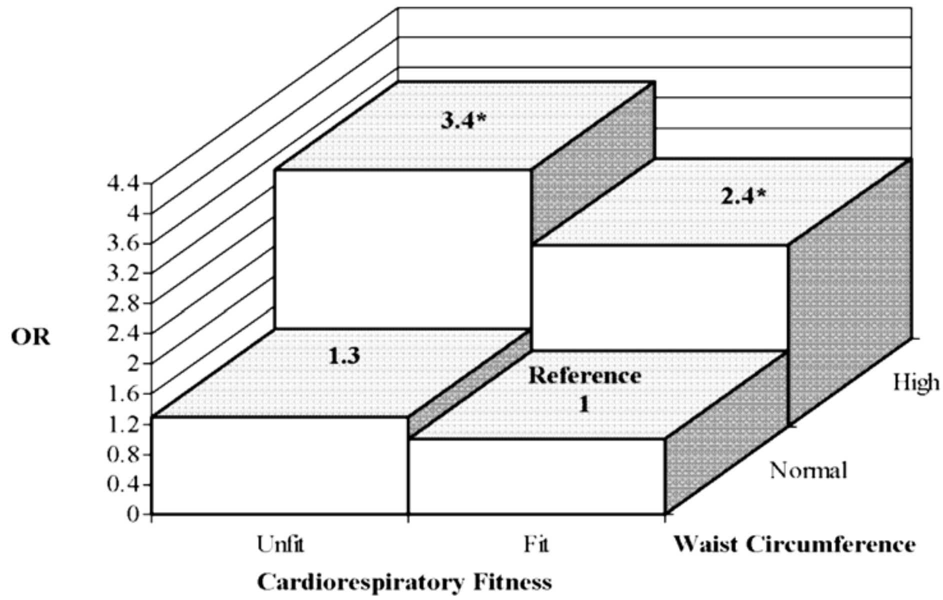

Figure 2a — Odds ratios for the joint association of WC and CRF and functional limitation within persons aged 30–49 years. * $P < .05$. OR = Odds ratio.

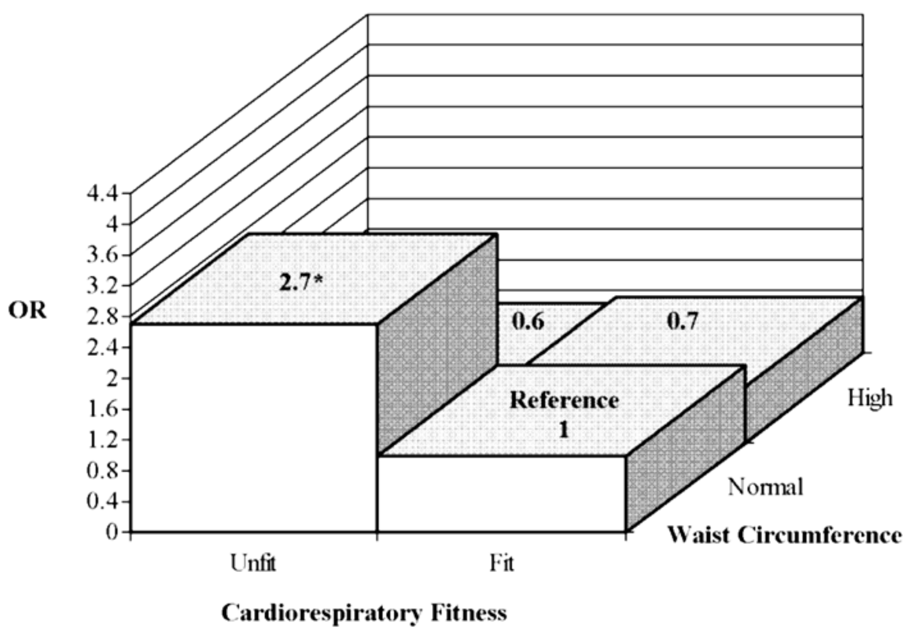

Figure 2b — Odds ratios for the joint association of WC and CRF and functional limitation within persons aged 50+ years. * $P < .05$. OR = Odds ratio.

inverse association between abdominal adiposity (WC) and incident functional limitation among older adults is unique to this study, compared with other studies that have found that higher levels of abdominal adiposity (WC) are positively associated with functional limitation in older adults.[5,13,14]

Several studies have found that overweight and obesity (measured by BMI, not WC) are positively associated with adverse health outcomes among younger adults, but inversely associated with adverse health outcomes among older adults. Imai and colleagues[6] found that among men with moderate obesity (measured by BMI), the risk of disability was elevated for ages 18 to 44 but lower for ages 65 and over. Among women aged 65 and over, overweight women had a lower risk of disability than normal weight women. In addition, previous studies have found that total adiposity has quantitatively different effects on mortality in older individuals compared with younger individuals.[27–29] Our previous work identified a J-shaped association between mortality and BMI, with mortality risk being greatest for older adults in the class II obesity group and lowest for older adults in the overweight group.[20] Researchers have speculated that the controversial interrelationship between adiposity (BMI and WC) and age in predicting health outcomes may be partially due to selective survival and cohort effects.[30,31]

Examination of the joint associations of BMI and CRF for predicting functional limitation revealed that the unfit group had greater odds of functional limitation than the fit group regardless of normal weight or overweight status. Among the fit group, persons who were overweight had greater odds of functional limitation than persons who were normal weight. However, the odds of functional limitation for the overweight or normal weight, unfit groups were greater than the odds of functional limitation for the overweight, fit group. These findings suggest CRF may be a stronger predictor of functional limitation than BMI in middle aged and older adults.

Examination of the joint associations of WC and CRF for predicting functional limitation among those aged 30 to 49 years revealed that the odds of functional limitation were highest among persons who were unfit with high WC. The odds of functional limitation were also significantly higher among fit persons with high WC compared with fit persons with normal WC. There was no significant difference in the odds of functional limitation between fit and unfit persons with normal WC. This supports the idea that, in younger persons, fitness as well as the avoidance of abdominal adiposity is important in protecting against functional limitation.

When examining the joint associations of CRF and WC among persons aged 50 and over the odds of functional limitation were greatest among those who were unfit with a normal WC. Furthermore, although not statistically significant, the odds of functional limitation were lower among those with a high WC in both the fit and unfit persons compared with the fit persons with normal WC. Our data suggests that both fitness and abdominal obesity are important in protecting against functional limitation. However, the exposure groups for the joint effects analyses had relatively small sample sizes; therefore, the results must be confirmed in larger studies.

Additional limitations to the current study include a focus on participants who were primarily white, well-educated, and had middle to upper socioeconomic status. The results may not apply to other groups of middle-aged and older adults. However, the homogeneity of our sample strengthens the internal validity of our findings by reducing confounding by unmeasured factors related to socioeconomic status, such as income or education. In addition, persons aged 50 and over were grouped together for statistical analyses to preserve sample size; however, older adults are a very heterogeneous group. Additional research examining the association between BMI, WC, and CRF and the development of functional limitation among various age groups (young old, old, old-old) within older adulthood may be of interest. Despite these limitations, this study provides further evidence regarding the complex relationships between fitness, adiposity, age, and functional status.

Study strengths include the use of standardized and objective measurements of fitness and adiposity. In addition, the baseline physical examination allowed for systematic evaluation of the presence or absence of baseline medical conditions. Furthermore, we are unaware of any other report that examines both the independent and joint association of CRF, BMI, and WC.

In conclusion, low CRF and high WC predicted the development of functional limitation in younger persons, whereas low CRF and normal WC predicted the development of functional limitation in older persons. It is recommended that clinicians evaluate older adults' weight history and comorbidity to provide a comprehensive assessment of the potential adverse and/or protective effects of overweight and obesity[32] as the evidence regarding the effects of abdominal adiposity on the development of functional limitation among older adults is inconsistent. In addition, we strongly recommend the promotion of regular physical activity among both middle aged and older adults for the prevention of incident functional limitations as the evidence from this study suggests CRF is a significant predictor of functional limitation independent of total adiposity, and in combination with abdominal adiposity among middle aged and older adults.

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