

Supplementary materials: Relative Hand Grip and Back Muscle Strength, but Not Mean Muscle Strength, as Risk Factors for Incident Metabolic Syndrome and Its Metabolic Components: 16 Years of Follow-Up in a Population-Based Cohort Study

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Table S1. Baseline characteristics according to sex.

		Women (n=1215)	Men (n=1323)	
General characteristics				
Age		47.9±7.0	47.8±6.8	0.727
Smoker	Ex-smoker	12 (1.0%)	469 (35.4%)	< 0.001
	Current smoker	23 (1.9%)	566 (42.8%)	
Family history of T2DM	Yes	192 (15.8%)	176 (13.3%)	0.074
	No	1023 (84.2%)	1147 (86.7%)	
Family history of hypertension	Yes	254 (20.9%)	264 (20.0%)	0.553
	No	961 (79.1%)	1059 (80.0%)	
Job	Blue color	365 (30.0%)	922 (69.7%)	< 0.001
	White color	50 (4.1%)	313 (23.7%)	
	House keeper	800 (65.8%)	88 (6.7%)	
Income (KRW)	< 1 million	184 (15.1%)	97 (7.3%)	< 0.001
	1–2	371 (30.5%)	367 (27.7%)	
	2–4	525 (43.2%)	643 (48.6%)	
	4 ≤	135 (11.1%)	216 (16.3%)	
Education	≤ 12 Years	1078 (88.7%)	900 (68.0%)	< 0.001
	12< Years	137 (11.3%)	423 (32.0%)	
Marry Status	Yes	1097 (90.3%)	1286 (97.2%)	< 0.001
Menopause Status	Yes	236 (19.4%)		
Body Mass Index (kg/m ²)		24.4±2.8	24.5±2.7	0.355
Height (Cm)		155.3±5.0	167.8±5.6	< 0.001
Weight (Kg)		58.8±7.2	69.1±8.9	< 0.001
Alcohol consumption (g/day)		1.5±5.4	19.3±27.5	< 0.001

Leisure physical activity (Met)	127.0±198.0	125.3±198.7	0.830
Metabolic Components			
Waist circumference (cm)	75.7±6.9	82.8±7.0	< 0.001
HDL-cholesterol (mg/dL)	53.1±11.7	47.5±10.3	< 0.001
Triglycerides (mg/dL)	112.1±63.4	155.5±92.5	< 0.001
Systolic Blood Pressure (mmHg)	111.3±15.6	116.7±14.9	< 0.001
Diastolic Blood Pressure (mmHg)	73.5±10.0	79.6±10.5	< 0.001
Muscle Strength			
Hand grip strength (HGS)			
Mean HGS (kg)	21.8±3.9	35.2±5.6	< 0.001
BMI-relative Mean HGS	0.90±0.19	1.45±0.26	< 0.001
Weight-relative Mean HGS	0.37±0.07	0.51±0.09	< 0.001
WC-relative Mean HGS	0.29±0.06	0.43±0.07	< 0.001
Back muscle strength (BMS)			
Mean BMS (kg)	42.7±12.1	83.9±19.2	< 0.001
BMI-relative Mean BMS	1.77±0.52	3.45±0.81	< 0.001
Weight-relative Mean BMS	0.73±0.21	1.22±0.29	< 0.001
WC-relative Mean BMS	0.57±0.16	1.02±0.24	< 0.001

Abbreviation: iMetS, incident metabolic syndrome; BMI, body mass index; WC, waist circumference.

Table S2. Sex adjusted partial correlation coefficient of relative hand grip strength and metabolic components.

	BMI	WC	Weight	HDL	TG	SBP	DBP	Fasting glucose	2hr glucose	Age
Mean HGS (kg)	0.099*	0.065*	0.262*	0.003	-0.062*	-0.035	0.005	-0.019	-0.111*	-0.232*
BMI-relative Mean HGS	-0.484*	-0.423*	-0.270*	0.159*	-0.177*	-0.145*	-0.136*	-0.093*	-0.169*	-0.227*
Weight-relative Mean HGS	-0.500*	-0.482*	-0.462*	0.159*	-0.159*	-0.136*	-0.150*	-0.116*	-0.144*	-0.172*
WC-relative Mean HGS	-0.302*	-0.410*	-0.137*	0.136*	-0.169*	-0.135*	-0.114*	-0.096*	-0.182*	-0.283*
Mean BMS (kg)	0.146**	0.111**	0.221**	-0.031	-0.013	-0.02	0.015	0.02	-0.035	-0.175**
BMI-relative Mean BMS	-0.276**	-0.245**	-0.155**	0.083**	-0.105**	-0.101**	-0.088**	-0.035	-0.087**	-0.185**
Weight-relative Mean BMS	-0.273**	-0.278**	-0.286**	0.079**	-0.087**	-0.090**	-0.095**	-0.048*	-0.062**	-0.140**
WC-relative Mean BMS	-0.135**	-0.225**	-0.055**	0.063**	-0.095**	-0.090**	-0.070**	-0.036	-0.092**	-0.216**

*, <0.01 ; **, <0.001

Table S3. Sensitivity analysis for adjusted Cox hazard ratios for inverse one standard deviation of relative hand grip strength and back muscle strength stratified by follow up time, gender and age subgroups.

	Follow-up exam	HGS		BMC	
		Women	Men	Women	Men
BMI-relative	3rd	1.241 (1.060-1.453) 0.007	1.275 (1.124-1.446) <0.001	1.146 (0.970-1.354) 0.110	1.081 (0.954-1.226) 0.222
	5th	1.210 (1.062-1.379) 0.004	1.249 (1.124-1.388) <0.001	1.178 (1.032-1.344) 0.015	1.107 (0.999-1.227) 0.053
	7th	1.187 (1.047-1.345) 0.007	1.232 (1.113-1.363) <0.001	1.128 (0.988-1.288) 0.074	1.079 (0.979-1.190) 0.125
	9th	1.494 (1.337-1.671) <0.001	1.470 (1.335-1.618) <0.001	1.192 (1.072-1.324) 0.001	1.212 (1.113-1.320) <0.001
Weight-relative	3rd	1.220 (1.050-1.418) 0.010	1.282 (1.134-1.450) <0.001	1.129 (0.962-1.324) 0.137	1.083 (0.956-1.228) 0.210
	5th	1.209 (1.068-1.370) 0.003	1.232 (1.115-1.361) <0.001	1.171 (1.032-1.329) 0.014	1.101 (0.994-1.220) 0.066
	7th	1.175 (1.039-1.328) 0.010	1.211 (1.099-1.334) <0.001	1.113 (0.980-1.265) 0.099	1.070 (0.970-1.180) 0.179
	9th	1.454 (1.306-1.620) <0.001	1.472 (1.342-1.614) <0.001	1.158 (1.044-1.283) 0.005	1.212 (1.114-1.317) <0.001
WC-relative	3rd	1.195 (1.011-1.412) 0.036	1.264 (1.113-1.436) <0.001	1.087 (0.917-1.289) 0.335	1.065 (0.936-1.210) 0.339
	5th	1.148 (1.002-1.316) 0.047	1.234 (1.110-1.373) <0.001	1.117 (0.977-1.277) 0.105	1.094 (0.985-1.215) 0.095
	7th	1.134 (0.995-1.292) 0.059	1.213 (1.094-1.344) <0.001	1.071 (0.937-1.225) 0.315	1.062 (0.961-1.174) 0.236
	9th	1.447 (1.293-1.620) <0.001	1.431 (1.302-1.574) <0.001	1.135 (1.022-1.261) 0.019	1.190 (1.092-1.297) <0.001

Abbreviation: HGS, handgrip strength; BMC, back muscle strength; BMI, body mass index; WC, waist circumference.

Table S4. Univariate hazard ratio (HR) of incident metabolic syndrome associated with quartile group of mean hand grip strength, back muscle strength, and relative muscle strength according to sex.

Muscle strength	Group	HGS		BMS	
		Women HR (95% CI) P	Men HR (95% CI) P	Women HR (95% CI) P	Men HR (95% CI) P
Mean (kg)	Q4	Reference	Reference	Reference	Reference
	Q3	0.978 (0.746-1.281) 0.870	1.048 (0.820-1.339) 0.708	1.150 (0.890-1.485) 0.285	0.877 (0.692-1.112) 0.279
	Q2	1.129 (0.872-1.462) 0.357	1.124 (0.884-1.429) 0.340	1.051 (0.802-1.376) 0.718	1.113 (0.884-1.401) 0.363
	Q1	1.259 (0.964-1.645) 0.091	1.192 (0.937-1.517) 0.152	1.170 (0.894-1.530) 0.253	0.938 (0.738-1.192) 0.600
	P value for linear trend	0.053	0.123	0.380	0.907
BMI-relative	Q4	Reference	Reference	Reference	Reference
	Q3	2.090 (1.506-2.901) < 0.001	1.398 (1.067-1.832) 0.015	1.872 (1.402-2.499) < 0.001	1.134 (0.881-1.460) 0.330
	Q2	2.756 (2.008-3.784) < 0.001	1.543 (1.183-2.012) 0.001	1.946 (1.458-2.598) < 0.001	1.511 (1.187-1.924) 0.001

Women	Variables	Baseline	8th follow-up	deta change	P value
	Mean HGS	21.8±3.8	20.9±4.1	0.816	< 0.001
	BMI-relative	0.90±0.19	0.87±0.20	0.029	< 0.001
	Weight-relative	0.37±0.07	0.36±0.07	0.012	< 0.001
	WC-relative	0.29±0.06	0.26±0.06	0.026	< 0.001
	Leisure physical activity	127.0±198.0	129.7±156.5	-2.713	0.716
Men	Mean HGS	35.2±5.6	35.7±6.5	-0.513	0.033
	BMI-relative	1.45±0.26	1.47±0.28	-0.023	0.036
	Weight-relative	0.51±0.09	0.52±0.09	-0.009	0.011
	WC-relative	0.43±0.07	0.42±0.08	0.012	< 0.001
	Leisure physical activity	125.3±198.7	198.8±260.0	-73.471	< 0.001
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	Q1	3.858 (2.822-5.274)	2.410 (1.870-3.105)	2.175 (1.628-2.906)	1.521 (1.194-1.938)
		< 0.001	< 0.001	< 0.001	0.001
P value for linear trend		< 0.001	< 0.001	< 0.001	< 0.001
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Weight-relative	Q4	Reference	Reference	Reference	Reference
	Q3	2.125 (1.541-2.931)	1.493 (1.135-1.963)	1.715 (1.287-2.286)	1.156 (0.897-1.489)
		< 0.001	0.004	< 0.001	0.262
	Q2	2.622 (1.912-3.596)	1.812 (1.388-2.366)	1.865 (1.402-2.481)	1.446 (1.137-1.840)
		< 0.001	< 0.001	< 0.001	0.003
	Q1	3.517 (2.581-4.791)	2.515 (1.946-3.250)	2.013 (1.508-2.687)	1.611 (1.269-2.044)
		< 0.001	< 0.001	< 0.001	< 0.001
P value for linear trend		< 0.001	< 0.001	< 0.001	< 0.001
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WC-relative	Q4	Reference	Reference	Reference	Reference
	Q3	1.909 (1.391-2.619)	1.516 (1.159-1.983)	1.720 (1.298-2.280)	0.980 (0.761-1.262)
		< 0.001	0.002	< 0.001	0.878
	Q2	2.694 (1.983-3.660)	1.716 (1.316-2.237)	1.718 (1.294-2.280)	1.377 (1.087-1.745)
		< 0.001	< 0.001	< 0.001	0.008
	Q1	3.268 (2.406-4.438)	2.353 (1.824-3.035)	2.102 (1.585-2.787)	1.434 (1.130-1.820)
		< 0.001	< 0.001	< 0.001	0.003
P value for linear trend		< 0.001	< 0.001	< 0.001	< 0.001

Abbreviation: HGS, handgrip strength; BMC, back muscle strength; BMI, body mass index; WC, waist circumference.

Table S5. Change of handgrip, relative handgrip, and leisure physical activity at baseline and 8th follow-up.

Women	Variables	Baseline	8th follow-up	deta change	P value
	Mean HGS	21.8±3.8	20.9±4.1	0.816	< 0.001
	BMI-relative	0.90±0.19	0.87±0.20	0.029	< 0.001
	Weight-relative	0.37±0.07	0.36±0.07	0.012	< 0.001
	WC-relative	0.29±0.06	0.26±0.06	0.026	< 0.001
	Leisure physical activity	127.0±198.0	129.7±156.5	-2.713	0.716
Men	Mean HGS	35.2±5.6	35.7±6.5	-0.513	0.033
	BMI-relative	1.45±0.26	1.47±0.28	-0.023	0.036
	Weight-relative	0.51±0.09	0.52±0.09	-0.009	0.011
	WC-relative	0.43±0.07	0.42±0.08	0.012	< 0.001

Leisure physical
activity

125.3±198.7

198.8±260.0

-73.471

< 0.001

Abbreviation: HGS, handgrip strength; BMI, body mass index; WC, waist circumference.

Table S6. Univariate hazard ratio (HR) of incident metabolic syndrome components associated with one standard deviation increase of mean hand grip strength, back muscle strength, and relative muscle strength according to sex.

	Waist	HDL	TG	HTN	DM
	HR (95% CI) P	HR (95% CI) P	HR (95% CI) P	HR (95% CI) P	HR (95% CI) P
Women					
Mean HGS (kg)	0.902 (0.800-1.018) 0.095	0.903 (0.806-1.011) 0.078	0.905 (0.822-0.997) 0.043	0.951 (0.861-1.049) 0.315	0.786 (0.682-0.905) 0.001
BMI-relative HGS	0.526 (0.461-0.600) < 0.001	0.876 (0.785-0.976) 0.017	0.806 (0.731-0.889) < 0.001	0.740 (0.667-0.821) < 0.001	0.611 (0.525-0.711) < 0.001
Weight-relative HGS	0.492 (0.432-0.561) < 0.001	0.881 (0.788-0.985) 0.026	0.821 (0.745-0.904) < 0.001	0.759 (0.685-0.842) < 0.001	0.648 (0.559-0.752) < 0.001
WC-relative HGS	0.574 (0.505-0.652) < 0.001	0.863 (0.774-0.962) 0.008	0.807 (0.731-0.890) < 0.001	0.739 (0.667-0.819) < 0.001	0.610 (0.526-0.708) < 0.001
BMS (kg)	0.973 (0.864-1.095) 0.648	0.917 (0.820-1.027) 0.135	0.936 (0.854-1.026) 0.160	0.957 (0.870-1.052) 0.361	0.875 (0.762-1.005) 0.059
BMI-relative BMS	0.666 (0.585-0.759) < 0.001	0.892 (0.797-0.997) 0.044	0.857 (0.781-0.939) 0.001	0.813 (0.736-0.897) < 0.001	0.725 (0.626-0.840) < 0.001
Weight-relative BMS	0.653 (0.574-0.744) < 0.001	0.899 (0.803-1.006) 0.064	0.875 (0.797-0.959) 0.005	0.836 (0.757-0.922) < 0.001	0.769 (0.666-0.888) < 0.001
WC-relative BMS	0.722 (0.636-0.820) < 0.001	0.888 (0.794-0.993) 0.037	0.866 (0.789-0.950) 0.002	0.820 (0.742-0.905) < 0.001	0.739 (0.639-0.855) < 0.001
Men					
Mean HGS (kg)	1.048 (0.795-1.382) 0.740	0.934 (0.853-1.023) 0.142	1.041 (0.944-1.149) 0.420	0.939 (0.858-1.027) 0.169	0.912 (0.816-1.020) 0.106
BMI-relative HGS	0.433 (0.317-0.590) < 0.001	0.803 (0.732-0.881) < 0.001	0.900 (0.817-0.991) 0.032	0.800 (0.732-0.875) < 0.001	0.687 (0.611-0.772) < 0.001
Weight-relative HGS	0.334 (0.248-0.449) < 0.001	0.818 (0.748-0.895) < 0.001	0.879 (0.799-0.966) 0.008	0.788 (0.722-0.861) < 0.001	0.692 (0.618-0.774) < 0.001
WC-relative HGS	0.464 (0.344-0.626) < 0.001	0.813 (0.742-0.891) < 0.001	0.895 (0.814-0.985) 0.023	0.816 (0.747-0.893) < 0.001	0.697 (0.622-0.781) < 0.001
BMS (kg)	1.230 (0.943-1.605) 0.127	1.031 (0.946-1.123) 0.492	1.047 (0.953-1.149) 0.339	0.967 (0.887-1.055) 0.453	1.074 (0.968-1.192) 0.180
BMI-relative BMS	0.667 (0.504-0.883) 0.005	0.931 (0.855-1.013) 0.097	0.954 (0.870-1.046) 0.316	0.866 (0.795-0.942) 0.001	0.881 (0.794-0.977) 0.017
Weight-relative BMS	0.559 (0.420-0.743) < 0.001	0.947 (0.870-1.031) 0.210	0.937 (0.855-1.027) 0.162	0.859 (0.790-0.935) < 0.001	0.888 (0.801-0.985) 0.024
WC-relative BMS	0.698 (0.529-0.920) 0.011	0.940 (0.863-1.024) 0.155	0.947 (0.864-1.039) 0.249	0.877 (0.806-0.955) 0.003	0.891 (0.803-0.988) 0.029

Abbreviation: HDL, high density lipoprotein-cholesterol ; TG, Triglyceride; HTN, hypertension; DM, diabetes; HGS, hand grip strength; BMS, back muscle strength; HR, hazard ratio, CI; confidence interval; BMI, body mass index; WC, waist circumference.