Long-term body mass trajectories and hypertension by sex among Chinese adults: a 24-y open cohort study

Short title: Trajectory of body mass and hypertension

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Characteristics	Total	Male	Female	Statistics	Р	
No. Participants	14262	6827	7435			
Total Person*years	137094	65794	71300			
Follow-up duration (year)	9.6±7.0	9.6 ±6.9	9.6±7.0	0.17	0.684	
No. Hypertension, n (%)	5138 (36.0)	2687 (39.4)	2451 (33.0)	63.11	<0.001	
Age (y)	38.8 ±14.2	38.2 ±14.3	39.3 ±14.1	24.27	<0.001	
Education year (y)	7.4 ±4.3	8.2±3.8	6.7±4.6	432.32	<0.001	
Rural, n (%)	9008 (63)	4393 (64)	4615 (62)	7.92	0.005	
Height(cm)	161.1 ±8.4	166.8 ±6.6	155.8 ±6.2	10540.50	<0.001	
Initial BMI(kg/m ²)	22.0 ±2.9	21.9 ±2.8	22.1 ±3.0	16.94	<0.001	
Lean (<18.5), n(%)	1226 (8.6)	554 (8.1)	672 (9.0)			
Normal (18.5-23.9), n(%)	9835 (69)	4873 (71)	4962 (67)			
Overweight (24-27.9), n(%)	2671 (19.0)	1168 (17)	1503 (20)	36.54	< 0.001	
Obesity (≥28.0) , n(%)	530 (3.7)	232 (3.4)	298 (4.0)			
Initial weight(kg)	57.3 ±9.8	61.1 (9.7)	53.7 (8.5)	2310.33	<0.001	
Initial smoker, n(%)	4706(33.0)	4401 (65)	305 (4.1)	5864.68	< 0.001	
Initial drinker, n(%)	5169 (36)	4262 (63)	907 (12)	3877.24	<0.001	
Initial SBP(mmHg)	112.2 ±11.8	114.2 ±11.0	110.3 ±12.1	405.53	< 0.001	
Initial DBP(mmHg)	73.1 ±8.2	74.4 ±7.8	72.0 ±8.4	316.54	< 0.001	

Supplementary Table S1 Characteristics of the participants including in the final analysis ‡

Initial Physical Activities (MET-hours/week)	65.8 ±95.9	49.0 ±96.6	81.2 ±92.4	393.05	< 0.001
Initial dietary energy (kcal)	2406.9 ±948.0	2615.2 ±840.0	2218.1 ±999.4	636.57	< 0.001
Current BMI(kg/m ²)	23.2 ±3.4	23.3 ±3.3	23.2 ±3.4	0.14	0.712
Lean (<18.5), n(%)	950 (6.7)	426 (6.2)	524 (7.0)		
Normal (18.5-23.9), n(%)	7745 (54.0)	3704 (54.0)	4041 (54.0)	9.59	
Overweight (24-27.9), n(%)	4274 (30.0)	2107 (31.0)	2167 (29.0)).3)	0.022
Obesity (≥28.0), n(%)	1293 (9.1)	590 (8.6)	703 (9.5)		
Current weight(kg)	60.5 (11.2)	64.9 (11.2)	56.4 (9.6)	2364.02	< 0.001
Current smoker, n(%)	4276 (30.0)	4024 (59.0)	252 (3.4)	5243.47	< 0.001
Current drinker, n(%)	4453 (31.0)	3869 (57.0)	584 (7.9)	4279.84	< 0.001
Current SBP(mmHg)	123.5 ±17.6	125.1 ±16.8	121.9 ±18.2	117.24	< 0.001
Current DBP(mmHg)	79.0 ±10.6	80.6 ±10.5	77.6 ±10.4	305.38	< 0.001
Current physical activities (MET hours/week)	131.6 ±131.6	133.7 ±140.7	129.5 ±123.2	3.51	0.061
Current dietary energy (kcal)	2086.2 ±1038.9	2283.9 ±1095.1	1904.9 ±949.0	488.05	< 0.001

 \ddagger Values in table are mean \pm SD or N (Percent); Missing data are handled in the analysis; BMI, body mass

index; SBP, systolic blood pressure; DBP, diastolic blood pressure

Supplementary Text. The model fitting procedure of BMI change trajectory and goodness of model fitting

Using a maximum-likelihood approach, LCTA estimated multiple regression models simultaneously and calculated from the model parameters the probability of each participants belonging to each trajectory group. The model fitting procedure of BMI change trajectory with Proc Traj is listed as follows:

Step 1. Decide on the optimal number of groups using substantive knowledge. Based on previous researches (1, 2) and our substantive knowledge about the long-term change of BMI characteristics, we decided to fit two- to five-group models of BMI change trajectories.

Step 2. Fit number of groups to data. To determine the optimal number of trajectory groups included in the model, we compared Bayesian Information Criteria (BIC) between models with different groups. A smaller BIC value indicated a better fit (3), but as the number of groups was increased across models, the additional reduction of BIC became smaller (**Supplementary Table S3**). Following the existing guidelines (4, 5), we chose the model when additional groups failed to increase BIC by at least half of the BIC in the previous model and the value of group membership probability $\geq 5\%$.

Step 3. Select the shape of the pattern of change for each group over time. After the number of groups was selected, we determined further the shape of each trajectory group using a stepwise approach in establishing polynomial order, with all groups initially set to cubic order. As the order of each trajectory was set to quadratic, linear, and intercept respectively, we compared the changes in BIC and the significance of parameters across models. Based on the substantive knowledge and statistical inference, the cubic trajectory pattern with four trajectory groups was regarded as the best fitting for the data.

Once a model was selected, we examined the posterior probabilities for each trajectory group to ensure all groups provided evidence for adequate model fitting. A general rule required an acceptable model to have a minimum average posterior probability of 0.70 for all trajectories (4). In this study, average posterior probabilities for all trajectories were at least 0.75 (**Supplementary Table S4**)

References

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Number of Groups	BIC		bability (%))		
Tumber of Groups	DIC	Group 1	Group 2	Group 3	Group 4	Group 5
2	-121977.99	58.70	41.30			
3	-117907.51	26.93	54.28	18.78		
4	-115720.08	9.19	41.47	38.09	11.25	
5	-114448.35	4.44	39.29	26.46	22.91	6.90

Supplementary Table S2. Tabulated Bayesian Information Criterion(BIC) for all participants

	BMI trajectory	Intercept	T	Quadratic		Group membership	
	change pattern	term	Linear term	term	Cubic term	probability (%)	Average posterior probability (%)
All participants	Loss	0.069	-0.651	0.051	1.0×10-3	7.94	84.6
	Stable	0.263	0.0293	-0.002	1.00×10-4	44.0	75.2
	Moderate gain	0.278	0.287	-0.009	1.90×10-4	38.1	75.5
	Substantial gain	0.070	0.882	-0.051	0.001	9.93	85.6
Male	Loss	0.027	-0.780	0.062	1.0×10-3	5.68	75.8
	Stable	0.303	-0.015	0.002	-	40.94	81.1
	Moderate gain	0.339	0.273	-0.010	2.3×10-4	40.85	79.3
	Substantial gain	0.224	0.866	-0.050	1.1×10-3	12.52	87.4
Female	Loss	0.039	-0.556	0.041	9.2×10-4	10.01	84.1
	Stable	0.229	0.016	0.001	-	46.90	76.7
	Moderate gain	0.195	0.305	-0.01	1.8×10-4	35.55	79.8
	Substantial gain	-0.117	0.894	-0.053	0.001	7.55	80.5

Supplementary Table S3. Parameters estimated for BMI trajectory change pattern ‡

[‡] Parameter estimate presented the shape of each pattern of trajectory over time. Intercept term interpreted as the expected level of change of BMI in kg/m² at the first year of follow-up. Linear term interpreted as the linear slope of change of BMI by follow-up year. Quadratic term interpreted as the quadratic slope and cubic term interpreted as the cubic slope.

Supplementary Table S4. Sensitivity analysis of the associations between different patterns of

BMI change trajectories	Exclude follow-up	≤4 yrs	Exclude chronic	diseases	Multiple Imputation	
Diffi change trajectories	HR(95% CI) †	P value	HR(95% CI) †	P value	HR(95% CI) †	P value
Male						
Loss	0.78 (0.63-0.96)	0.018	0.69(0.56-0.85)	0.001	0.72(0.61-0.85)	0.001
Stable	Ref.		Ref.		Ref.	
Moderate gain	1.26 (1.14-1.39)	< 0.001	1.22(1.12-1.34)	< 0.001	1.21(1.12-1.32)	< 0.001
Substantial gain	1.79 (1.56-2.06)	< 0.001	1.65(1.45-1.88)	< 0.001	1.64(1.44-1.87)	< 0.001
Female						
Loss	0.82 (0.70-0.98)	0.025	0.92(0.79-1.08)	0.327	0.85(0.73-1.00)	0.046
Stable	Ref.		Ref.		Ref.	
Moderate gain	1.30 (1.18-1.44)	< 0.001	1.29(1.17-1.42)	< 0.001	1.28(1.17-1.40)	< 0.001
Substantial gain	1.86 (1.58-2.20)	< 0.001	1.93(1.65-2.26)	< 0.001	1.86(1.62-2.14)	< 0.001

BMI trajectories and the risk of hypertension ‡

 \ddagger all models adjusted variables including age at baseline, survey wave, BMI at baseline, initial SBP and

DBP, current smoking and alcohol consumption, current physical activity and dietary energy intake.

† HR, hazard ration. CI, confidence interval

Characteristics	Analytic sample	Excluded sample	Statistics*	Р
No. Participants	14262	18232		
Male(%)	6827(47.9)	8930(48.9)	3.96	0.047
Age (y)	38.8 ±14.2	22.7 ± 19.1	88.11	< 0.001
Education year (y)	7.4 ± 4.3	7.6 ± 4.4	4.11	< 0.002
Rural, n(%)	9008 (63.0)	10939(90.0)	33.75	< 0.001
Initial weight(kg)	57.3±9.8	42.3±21.7	76.66	< 0.002
Initial BMI (kg/m ²)	22.0 ±2.9	19.9±5.0	44.63	< 0.001
Initial SBP(mmHg)	112.2 ±11.8	110.7±20.1	7.91	< 0.001
Initial DBP(mmHg)	73.1 ±8.2	71.2±20.1	10.06	< 0.001
Initial smoker, n(%)	4706 (33.0)	4193(23.0)	402.30	< 0.001
Initial drinker, n(%)	5169 (36.0)	4011(21.9)	800.91	< 0.001
Physical Activities(MET-hours/week)	65.8±95.9	87.1±102.5	19.14	< 0.001
Dietary Total Energy(kcal)	2086.2 ±1038.9	1759.3±1422.0	23.06	< 0.001

Supplementary Table S5 Characteristics of participants in analytic sample and excluded samples †

† Values in table are mean ±SD or N (Percent); Missing data are handled in the analysis; BMI, body mass

index; SBP, systolic blood pressure; DBP, diastolic blood pressure

* t test for continuous variable and Chi square for category variable.

	Loss V.S Stable		Moderate gain V.S Stable			Substantial gain V.S Stable			
lypertension		Events/Total (%) Hazard Risk (95% CI)	-	Events/Total (%)	Hazard Risk (95% CI)		Events/Total (%)	Hazard Risk (95% CI)	
Total		139/388 (35.8%) 0.74 (0.62-0.89)	⊢⊷	1121/2789 (40.2%)	1.23 (1.13-1.34)	⊢ +-1	363/855 (42.5%)	1.65 (1.45-1.86)	P Valu
BMI at enrollment									0.118
Lean (<18.5 kg/m2)		0/1 (0.0%)	⊢ • − − − −	78/293 (26.6%)	1.27 (0.89-1.81)		32/110 (29.1%)	1.64 (1.02-2.64)	
Normal (18.5~23.9kg/m2)	⊢ ⊢ •−−−1	52/129 (40.3%) 1.07 (0.80-1.42)	⊢⊷⊣	839/2152 (39.0%)	1.23 (1.11-1.36)	⊢⊷⊣	285/657 (43.4%)	1.69 (1.46-1.95)	
Overweight (24~27.9kg/m2)	⊢ •−−1	59/180 (32.8%) 0.71 (0.53-0.95)	⊢ •−−−	182/308 (59.1%)	1.34 (1.10-1.63)	⊢ •−−−1	42/81 (51.9%)	1.70 (1.21-2.38)	
Obesity (≥28kg/m2)	⊢ •−−−1	28/78 (35.9%) 0.48 (0.30-0.79)		22/36 (61.1%)	0.93 (0.55-1.58)	├ ─•	4/7 (57.1%)	0.94 (0.32-2.79)	
Urbanization									0.708
Urban	⊢ •−−−†	56/174 (32.2%) 0.63 (0.47-0.86)	⊢ ⊷–∣	330/965 (34.2%)	1.14 (0.97-1.33)	⊢+	112/302 (37.1%)	1.55 (1.24-1.94)	
Rural	⊢ •−+I	83/214 (38.8%) 0.82 (0.65-1.04)	⊢⊷⊣	791/1824 (43.4%)	1.25 (1.13-1.39)	⊣	251/553 (45.4%)	1.67 (1.44-1.94)	
Age at enrollment									0.507
≤ 40 year	⊢ •i	53/200 (26.5%) 0.74 (0.55-1.00)		611/1818 (33.6%)	1.33 (1.17-1.51)	⊢⊷⊣	258/645 (40.0%)	1.89 (1.60-2.21)	
41~60 years	⊢ ⊷ _+	58/132 (43.9%) 0.76 (0.57-1.02)		392/763 (51.4%)	1.12 (0.98-1.28)	┝╼╾┤	85/174 (48.9%)	1.28 (1.01-1.62)	
> 60 year	⊢ • – – – – – – – – – – – – – – – – – –	28/56 (50.0%) 0.69 (0.45-1.06)	⊢ →−−−1	118/208 (56.7%)	1.43 (1.11-1.85)	↓ →	20/36 (55.6%)	2.12 (1.28-3.52)	
Smoking									0.479
never_never	⊢ ∙	34/106 (32.1%) 0.71 (0.49-1.04)	⊢ •−−1	227/666 (34.1%)	1.24 (1.03-1.50)		84/228 (36.8%)	1.68 (1.29-2.19)	
never_smoker		12/53 (22.6%) 0.34 (0.17-0.69)	→ →→	110/290 (37.9%)	1.31 (0.99-1.73)	⊢ •−−1	32/109 (29.4%)	1.18 (0.78-1.80)	
smoker_quit	⊢ → →	28/74 (37.8%) 0.71 (0.47-1.09)	⊢ •−-	216/446 (48.4%)	1.15 (0.95-1.41)	⊢•	88/166 (53.0%)	1.71 (1.31-2.23)	
smoker_smoker	⊢ → →→	65/153 (42.5%) 1.13 (0.87-1.47)		565/1378 (41.0%)	1.19 (1.05-1.34)	⊢⊷⊣	157/347 (45.2%)	1.57 (1.31-1.89)	
Drinking									0.149
non_drinker_non_drinker		29/98 (29.6%) 0.83 (0.56-1.25)		233/633 (36.8%)	1.37 (1.13-1.66)		81/207 (39.1%)	2.04 (1.55-2.70)	
non_drinker_drinker	 - • 	16/62 (25.8%) 0.40 (0.22-0.71)	⊢ •	129/378 (34.1%)	0.98 (0.76-1.26)	⊢ •−−-	57/148 (38.5%)	1.45 (1.05-2.01)	
drinker_non_drinker		43/91 (47.3%) 0.97 (0.68-1.38)	⊢ →−-	251/535 (46.9%)	1.38 (1.15-1.65)	⊢⊷⊣	74/155 (47.7%)	1.78 (1.36-2.33)	
drinker_drinker	⊢ − +	51/135 (37.8%) 0.90 (0.67-1.20)	⊢ •	503/1231 (40.9%)	1.11 (0.98-1.26)	⊢⊷⊣	148/339 (43.7%)	1.37 (1.13-1.65)	
Physical activity status									0.26
Increase	⊢ • 	96/228 (42.1%) 0.81 (0.65-1.01)	⊢⊷	840/1791 (46.9%)	1.22 (1.11-1.35)	⊢⊷⊣	286/568 (50.4%)	1.73 (1.50-1.99)	
Decrease		43/160 (26.9%) 0.61 (0.44-0.86)		281/998 (28.2%)	1.28 (1.08-1.51)		77/287 (26.8%)	1.44 (1.11-1.86)	
Dietary energy intake									0.817
Increase		31/91 (34.1%) 0.75 (0.51-1.11)		309/829 (37.3%)	1.25 (1.06-1.47)		114/257 (44.4%)	1.80 (1.43-2.26)	
Decrease	⊢ •−	108/297 (36.4%) 0.74 (0.60-0.92)	⊢⊷⊣	812/1960 (41.4%)	1.22 (1.11-1.35)	++-	249/598 (41.6%)	1.60 (1.38-1.86)	
	0.0 0.4 0.8 1.2 1.0 Hazard Risk	6 2.0	0.0 0.4 0.8 1.2 1.6 2.0 Hazard Risk)	0.	.0 0.8 1.6 2.4 3.2 4. Hazard Risk	0		

Supplementary Fig.S1. Subgroup analysis for the associations between different patterns of BMI trajectories and the risk of hypertension in males.

	Loss V.S Stable			Moderate gain V.S Stable			Extensive gain V.S Stable			
ypertension		Events/Total (%)	Hazard Risk (95% CI)	-	Events/Total (%)	Hazard Risk (95% CI)		Events/Total (%)	Hazard Risk (95% CI)	i) Interactio
Total	⊢∙-	259/744 (34.8%)	0.87 (0.75-1.00)		924/2643 (35.0%)	1.28 (1.17-1.40)	⊢•1	224/561 (39.9%)	Interaction 2.12)	P Value
BMI at enrollment										0.004
Lean (<18.5 kg/m2)		6/9 (66.7%)	1.52 (0.63-3.66)		82/364 (22.5%)	0.96 (0.68-1.34)	 • •	20/91 (22.0%)	1.33 (0.77-2.29)	
Normal (18.5~23.9kg/m2)		72/263 (27.4%)	1.02 (0.80-1.31)		638/1888 (33.8%)	1.42 (1.27-1.59)		168/399 (42.1%)	2.02 (1.70-2.40)	
Overweight (24~27.9kg/m2)	⊢ ⊷ ⊣	113/319 (35.4%)	0.77 (0.62-0.97)		185/360 (51.4%)	1.22 (1.01-1.48)		35/67 (52.2%)	1.74 (1.21-2.49)	
Obesity (≥28kg/m2)		68/153 (44.4%)	0.76 (0.53-1.10)		19/31 (61.3%)	0.75 (0.41-1.35)	· ·	1/4 (25.0%)	1.41 (0.19-10.56)	
Urbanization										0.828
Urban		100/313 (31.9%)	0.74 (0.58-0.94)		263/915 (28.7%)	1.28 (1.08-1.51)		68/218 (31.2%)	1.92 (1.46-2.52)	
Rural	⊢ •	159/431 (36.9%)	0.94 (0.78-1.13)	⊢ •−1	661/1728 (38.3%)	1.28 (1.15-1.43)	⊢⊷-1	156/343 (45.5%)	1.81 (1.52-2.17)	
Age at enrollment										0.548
≤ 40 year	⊢ •−−1	70/356 (19.7%)	0.73 (0.56-0.97)		469/1731 (27.1%)	1.41 (1.22-1.62)		129/382 (33.8%)	2.14 (1.74-2.63)	
41~60 years	⊢ →;	128/289 (44.3%)	0.91 (0.74-1.12)		357/725 (49.2%)	1.16 (1.01-1.33)		67/134 (50.0%)	1.58 (1.22-2.06)	
> 60 year	⊢ ⊷ 1	61/99 (61.6%)	0.93 (0.66-1.29)	⊢ • i	98/187 (52.4%)	1.21 (0.94-1.56)	⊢ • − − +	28/45 (62.2%)	1.66 (1.08-2.54)	
Smoking										0.475
never_never	⊢ ⊷-]	234/685 (34.2%)	0.87 (0.75-1.02)	⊢+	854/2487 (34.3%)	1.32 (1.20-1.45)	⊢+	211/536 (39.4%)	1.86 (1.59-2.16)	
never_smoker	•	6/16 (37.5%)	1.08 (0.37-3.16)		12/34 (35.3%)	0.62 (0.23-1.65)		3/6 (50.0%)	5.35 (1.16-24.76)	
smoker_quit		8/17 (47.1%)	0.71 (0.28-1.81)		25/58 (43.1%)	0.72 (0.38-1.39)	- •	5/9 (55.6%)	1.26 (0.43-3.70)	
smoker_smoker		7/17 (41.2%)	0.91 (0.37-2.22)		27/50 (54.0%)	0.94 (0.52-1.72)		5/6 (83.3%)	3.38 (1.13-10.11)	
Drinking										0.75
non_drinker_non_drinker	⊢•	213/618 (34.5%)	0.85 (0.73-1.00)	⊢⊷-	772/2163 (35.7%)	1.30 (1.18-1.44)		176/448 (39.3%)	1.77 (1.50-2.09)	
non_drinker_drinker	⊢	12/37 (32.4%)	1.25 (0.61-2.56)	⊢	34/132 (25.8%)	1.26 (0.78-2.04)	⊢ • − − −	14/30 (46.7%)	2.46 (1.31-4.64)	
drinker_non_drinker		25/59 (42.4%)	1.07 (0.66-1.74)		91/253 (36.0%)	1.15 (0.86-1.54)		28/65 (43.1%)	2.40 (1.54-3.75)	
drinker_drinker	• • · · · · · · · · · · · · · · · ·	4/17 (23.5%)	0.52 (0.17-1.55)		20/69 (29.0%)	0.87 (0.48-1.60)	•	4/10 (40.0%)	1.66 (0.27-10.11)	
Physical activity status										0.57
Increase	⊢+	161/449 (35.9%)	0.83 (0.70-1.00)	⊢⊷⊣	656/1717 (38.2%)	1.31 (1.17-1.46)	⊢ ⊷⊣	155/366 (42.3%)	2.03 (1.69-2.43)	
Decrease	⊢ →→	98/295 (33.2%)	0.91 (0.71-1.16)		268/926 (28.9%)	1.20 (1.02-1.41)		69/195 (35.4%)	1.53 (1.18-1.99)	
Dietary energy intake										0.43
Increase		61/192 (31.8%)	0.80 (0.59-1.07)		236/719 (32.8%)	1.44 (1.20-1.73)		62/154 (40.3%)	1.95 (1.46-2.60)	
Decrease	⊢ •	198/552 (35.9%)	0.90 (0.76-1.07)	++	688/1924 (35.8%)	1.22 (1.10-1.36)	⊢+-1	162/407 (39.8%)	1.79 (1.50-2.13)	

Supplementary Fig.S2. Subgroup analysis for the associations between different patterns of BMI trajectories and the risk of hypertension in females.

Supplementary Fig.S3. the directed acyclic graph among the potential covariates in the association between the pattern of longitudinal BMI change trajectories and hypertension

