· 流行病与统计方法 ·

中国中老年人动力性腹型肥胖与糖尿病发病风险的相关性分析

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摘要:目的　探讨动力性腹型肥胖(即握力降低合并腹型肥胖)与中国中老年人糖尿病发病风险的相关性。**方法**　基于中国健康与养老追踪调查(China Health and Retirement Longitudinal Study, CHARLS)2011—2015 年数据,纳入4 556 名基线无糖尿病的≥45 岁中老年人。根据握力(男性 <28 kg、女性 <18 kg)和腰围(男性≥90 cm、女性≥85 cm)将研究对象分为四组:无动力学障碍且无腹型肥胖(ND/NAO)、单纯腹型肥胖(ND/AO)、单纯动力学障碍(D/NAO)和动力性腹型肥胖(D/AO)。采用 Cox 比例风险模型分析各组与糖尿病发病风险的关联,并通过亚组分析探讨不同分组下动力性腹型肥胖与糖尿病发病风险的关联。**结果**　平均随访 4 年,新发糖尿病 495 例,发病率 10.9%,发病密度 27.2/千人年。多因素调整后,与 ND/NAO 组相比,ND/AO 组糖尿病发病风险增加 71%(*HR* = 1.709,95% *CI*:1.395 ~2.095),D/AO 组风险增加 123%(*HR* = 2.226,95% *CI*:1.472 ~3.366),而 D/NAO 组风险无显著差异(*P* > 0.05),亚组分析显示结果一致。**结论**　动力性腹型肥胖显著增加中国中老年人糖尿病发病风险,且风险高于单纯腹型肥胖。

关键词:动力性腹型肥胖、糖尿病、纵向研究
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Association between dynapenic abdominal obesity and the risk of diabetes mellitus in middle - aged and older Chinese adults

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Abstract: Objective　To investigate the association between dynapenic abdominal obesity (characterized by reduced handgrip strength combined with abdominal obesity) and the risk ofdiabetes in middle - aged and older Chinese adults. **Methods**　Using data from the China Health and Retirement Longitudinal Study (China Health and Retirement Longitudinal Study, CHARLS) 2011 - 2015, 4 556 participants aged ≥45 years without diabetes at baseline were included. Based on handgrip strength (men <28 kg, women <18 kg) and waist circumference (men ≥90 cm, women ≥85 cm), participants were categorized into four groups: non - dynapenic/non - abdominal obesity (ND/NAO), non - dynapenic/abdominal obesity (ND/AO), dynapenic/non - abdominal obesity (D/NAO), and dynapenic abdominal obesity (D/AO). Cox proportional hazards models were employed to analyze the association between each group and diabetes risk, and subgroup analysis was conducted to explore the association between dynapenic abdominal obesity and the risk of diabetes onset under different groupings. **Results**　After a mean follow - up of 4 years, 495 new cases of diabetes mellitus were recorded, representing an incidence rate of 10.9% and an incidence density of 27.2 per 1 000 person - years. Following multivariable adjustment, compared with the ND/NAO group, the ND/AO group exhibited a 71% increased risk of diabetes onset (*HR* = 1.709, 95% *CI*: 1.395 - 2.095), while the D/AO group showed a 123% increased risk (*HR* = 2.226, 95% *CI*: 1.472 - 3.366). No significant difference was observed in the D/NAO group (*P* > 0.05), with subgroup analyses yielding consistent results. **Conclusion**　Dynapenic abdominal obesity significantly increases the risk of diabetes among middle - aged and older Chinese adults, with a higher risk than abdominal obesity alone.

Keywords: Dynapenic abdominal obesity; Diabetes mellitus; Longitudinal study

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糖尿病已成为我国重大的公共卫生问题[1]。最新流行病学数据显示,中国糖尿病患者总数已高达 2.33 亿,总体患病率达 13.7%,且患病率仍呈持续上升趋势[2]。肥胖是驱动糖尿病流行的关键危险因素[3],研究指出,我国成人肥胖率已从 2002 年的 7.1%攀升至 2019 年的 16.4%[4]。在肥胖的不同类型中,腹型肥胖因与内脏脂肪堆积及胰岛素抵抗密切相关而备受关注[5]。肌肉不仅是运动系统的重要组成部分,更在葡萄糖代谢中发挥着核心作用[6],既往研究表明低骨骼肌质量合并腹型肥胖与糖尿病患病风险相关[7],近年有学者提出"动力性腹型肥胖"这一复合概念,指肌肉功能减退与腹型肥胖并存的状态,这种状态可能通过协同作用加剧糖代谢紊乱。但目前对这一复合表型在糖尿病发生中的联合作用尚缺乏系统探讨,尤其缺乏基于大规模人群的前瞻性证据。因此,本研究旨在通过一项前瞻性队列研究,探讨动力性腹型肥胖与糖尿病发病风险之间的关联,为早期识别高危人群和制定针对性干预策略提供科学依据。

1 资料与方法

1.1 研究对象 本研究数据来源于中国健康与养老追踪调查(CHARLS)项目 2011 年和 2015 年的调查数据,由研究者申请并获得许可使用。CHARLS 是由北京大学组织实施的一项全国性大型队列研究,旨在系统收集中国中老年人群的健康状况、社会经济背景与养老保障等方面的代表性数据[8]。数据内容涵盖详细的人口学特征、健康状况、体力活动水平、疾病史、生活方式、认知功能以及血液生物标志物等多个维度。本研究调查对象纳入标准为:(1)完成 2011 基线及 2015 年随访;(2)基线年龄≥45 岁;(3)FBG、HbA1c 等血液生化指标及握力等人口测量学指标完整。排除标准为:(1)基线时诊断为糖尿病;(2)2 次血液生化指标及人口测量学指标缺失。最终纳入研究对象 4 556 人(图 1)。

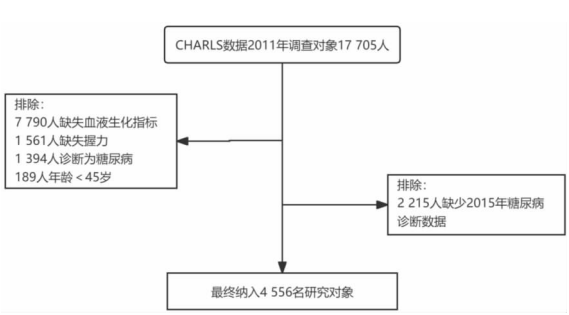


图 1 研究对象筛选过程

Fig. 1 Research subject selection process

1.2 调查问卷内容 包括研究对象的性别、年龄、婚姻状态、居住地、吸烟史、饮酒史、自我报告的个人疾病史(高血压、高血脂、糖尿病、恶性肿瘤病史及心脑血管疾病史等)等。

1.3 血液检测及体格检查内容 包括身高、体重、腰围、收缩压、舒张压、空腹血糖(Fasting Blood Glucose, FBG)、糖化血红蛋白(Glycated Hemoglobin, HbA1c)、总胆固醇(Total Cholesterol, TC)、低密度脂蛋白胆固醇(Low-Density Lipoprotein Cholesterol, LDL-C)、高密度脂蛋白胆固醇(High-Density Lipoprotein Cholesterol, HDL-C)、甘油三酯(Triglyceride, TG)等。

1.4 疾病诊断

1.4.1 2 型糖尿病 2 型糖尿病诊断依据《中国糖尿病防治指南》(2024 年版)[9],空腹血糖≥7.0 mmol/L(126 mg/dl)、糖耐量试验 2 h 血糖≥11.1 mmol/L(200 mg/dl)或糖化血红蛋白≥6.5%;自我报告的糖尿病病史或正在接受降糖治疗。

1.4.2 动力性腹型肥胖 DAO 使用握力和腰围来确定[10]。根据 2019 年亚洲肌肉减少症工作组(AWGS)[11],肌肉质量减少定义为男性握力<28 kg,女性握力<18 kg。腹型肥胖定义为男性腰围≥90 cm,女性腰围≥85 cm。所有研究对象根据动力学和腹型肥胖状态分为 4 组:无动力学障碍和无腹型肥胖(ND/NAO)、单纯腹型肥胖(ND/AO)、单纯动力学障碍(D/NAO)和动力性腹型肥胖(D/AO)。

1.5 统计分析 本研究数据分析采用 SPSS 27.0 和 R 4.5.0 统计软件完成,对于符合正态分布的计量数据,采用 $\bar{x} \pm s$ 表示,两组间比较采用独立样本 t 检验。偏态分布的计量资料则采用[$M(P_{25}, P_{75})$]表示,两组间比较采用 Mann Whitney U 检验。计数资料用例数和率[n(%)]表示,组间比较应用χ^2检验。采用多因素 Cox 比例风险回归模型分析动力性腹型肥胖与糖尿病发病的相关性。检验水准 $\alpha = 0.05$。

2 结 果

2.1 调查对象基线特征 基线共纳入 4 556 名研究对象,与未发生糖尿病组相比,发生糖尿病组年龄较大,女性居多,高血压病史、心脏疾病史、脑卒中病史和动力性腹型肥胖(D/AO)比例更高,已婚比例更低且 BMI、SBP、DBP、WC、TG、TC、FBG、HbA1c 的平均水平较高,HDL-C、握力的平均水平较低(表 1)。

2.2 随访后糖尿病的发病情况 经过平均 4 年的随访,新发糖尿病 495 人,发生率为 10.9%,发病密度为 27.2/千人年。ND/NAO 组的发生率为 7.3%,ND/AO 组的发生率为 15.2%,D/NAO 组的发生率为 10.4%,D/AO 组的发生率为 21.9%。与 ND/NAO 组

相比，ND/AO 组、D/AO 组的发病率更高，且差异有统计学意义（$P<0.001$），D/NAO 组的差异无统计学意义（$P>0.05$）（图 2）。

表 1　调查对象基于糖尿病分组的基线特征

Table 1　Baseline characteristics grouped according to the occurrence of diabetes

变量	未发生糖尿病	发生糖尿病	$t/z/\chi^2$	P 值
总体[n(%)]	4 061(89.1)	495(10.9)		
年龄(岁，$\bar{x}\pm s$)	58.72±8.76	60.34±8.82	−3.877	<0.001
BMI[kg/m^2，$M(P_{25},P_{75})$]	22.90(20.75,25.39)	24.39(21.68,27.16)	−2.251	<0.001
SBP(mm Hg，$\bar{x}\pm s$)	127.40±20.78	131.74±19.93	−4.406	<0.001
DBP(mm Hg，$\bar{x}\pm s$)	74.62±12.05	77.00±12.28	−4.139	<0.001
TG[mg/dl，$M(P_{25},P_{75})$]	100.00(72.60,143.37)	112.39(80.54,165.49)	−5.268	<0.001
TC(mg/dl，$\bar{x}\pm s$)	192.74±37.20	197.17±36.89	−2.504	0.012
LDL−C(mg/dl，$\bar{x}\pm s$)	117.48±33.70	120.07±33.83	−1.615	0.106
HDL−C(mg/dl，$\bar{x}\pm s$)	52.38±15.01	49.69±15.12	3.752	<0.001
FBG(mg/dl，$\bar{x}\pm s$)	99.76±10.57	104.72±10.10	−9.827	<0.001
HbA1c(%，$\bar{x}\pm s$)	5.10±0.37	5.31±0.41	−11.904	<0.001
WC(cm，$\bar{x}\pm s$)	83.51±11.91	87.64±11.90	−7.287	<0.001
握力(kg，$\bar{x}\pm s$)	32.98±10.14	31.25±9.79	3.594	<0.001
性别[n(%)]				
男	1 893(46.6)	197(39.8)		
女	2 168(53.4)	298(60.2)	8.256	0.004
居住地[n(%)]				
城市	1 339(33.0)	149(30.1)		
农村	2 722(67.0)	346(69.9)	1.654	0.198
婚姻[n(%)]				
已婚	3 657(89.3)	426(86.1)		
其他	434(10.7)	69(13.9)	4.752	0.029
高血压病史[n(%)]				
有	1 743(42.9)	291(58.8)		
无	2 318(57.1)	204(41.2)	44.951	<0.001
心脏疾病史[n(%)]				
有	446(11.0)	77(15.6)		
无	3 615(89.0)	418(84.4)	9.080	0.003
脑卒中病史[n(%)]				
有	67(1.6)	21(4.2)		
无	3 994(98.4)	474(95.8)	15.656	<0.001
吸烟史[n(%)]				
有	1 577(38.8)	178(36.0)		
无	2 484(61.2)	317(64.0)	1.538	0.215
饮酒史[n(%)]				
有	1 584(39.0)	184(37.2)		
无	2 477(61.0)	311(62.8)	0.625	0.429
分组[n(%)]				
ND/NAO	2 278(56.1)	180(36.4)		
ND/AO	1 442(35.5)	259(52.3)		
D/NAO	241(5.9)	28(5.7)		
D/AO	100(2.5)	28(5.6)	81.331	<0.001

2.3　*动力性腹型肥胖与糖尿病发病风险的 COX 回归分析*　结果显示：在调整多个混杂因素后，与 ND/NAO 组相比，ND/AO 组糖尿病的发病风险增加了 71%（$HR=1.709$，95% CI：1.395 ~2.095），D/AO 组糖尿病的发病风险增加了 123%（$HR=2.226$，95% CI：1.472 ~3.366）；D/NAO 组糖尿病的发病风险与 ND/NAO 组相比无明显差异（$P>0.05$）（表 2）。

2.4　*动力性腹型肥胖与糖尿病发病风险的亚组分析*　将性别、年龄、高血压病史、吸烟史、饮酒史 5 个变量作为分组变量进行亚组分析。与 ND/NAO 相比，各组 ND/AO 组和 D/AO 组糖尿病发病风险均增加，但交互作用 P 值均大于 0.05（图 3）。

3　讨　论

本研究基于中国健康与养老追踪调查（CHARLS）数据，探讨动力性腹型肥胖与中国中老年

表 2 动力性腹型肥胖与糖尿病发病风险的相关性

Table 2 The correlation between dynamic abdominal obesity and the risk of diabetes

分组	模型 1		模型 2		模型 3	
	HR(95% *CI*)	*P* 值	*HR*(95% *CI*)	*P* 值	*HR*(95% *CI*)	*P* 值
ND/NAO	1		1		1	
ND/AO	2.079(1.719 ~2.515)	<0.001	2.101(1.725 ~2.560)	<0.001	1.709(1.395 ~2.095)	<0.001
D/NAO	1.421(0.955 ~2.117)	0.083	1.249(0.833 ~1.871)	0.282	1.338(0.894 ~2.003)	0.157
D/AO	2.987(2.006 ~4.448)	<0.001	2.570(1.701 ~3.881)	<0.001	2.226(1.472 ~3.366)	<0.001

注:模型 1 未调整;模型 2 调整了性别、年龄、婚姻、居住地;模型 3 进一步调整了吸烟史、饮酒史、高血压病史、FBG、HbA1c。

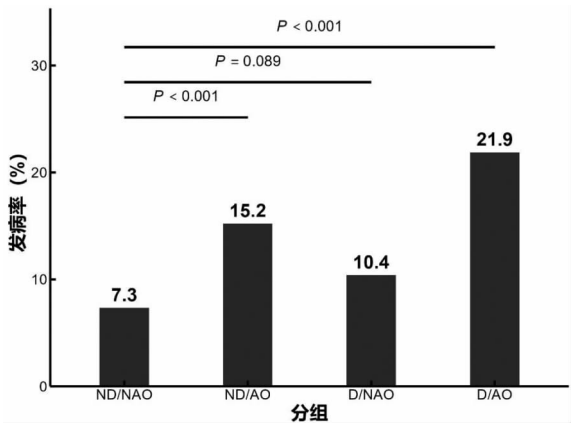


图 2 随访后糖尿病的发病情况

Fig. 2 Incidence of diabetes mellitus following follow – up

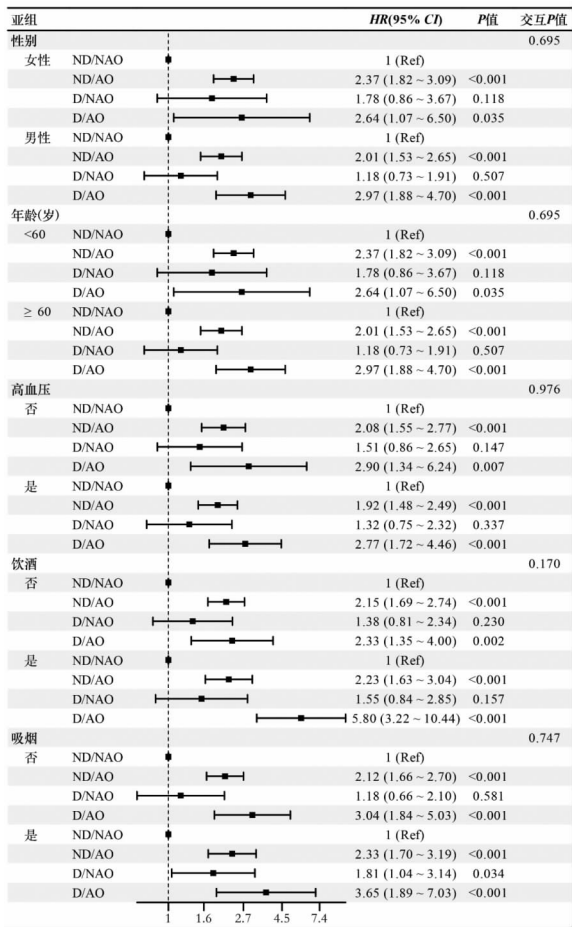


图 3 动力性腹型肥胖与糖尿病发病风险的亚组分析

Fig. 3 Subgroup analysis of the association between dynapenic abdominal obesity and diabetes risk

人糖尿病发病风险之间的关联。经过平均 4 年的随访,共新发糖尿病 495 例,发病率为 10.9%,发病密度为 27.2/千人年,这一发病率与国内外其他基于中老年人群的研究结果相近[12-13],提示中国中老年人群糖尿病疾病负担较为严峻,应予以充分重视。

本研究发现,动力性腹型肥胖(D/AO)与糖尿病发病风险有较强的关联强度(*HR* = 2.226),一项韩国的横断面研究同样报告了肌肉减少性肥胖与糖尿病的关联(*OR* = 2.16,95% *CI*:1.08 ~3.27)[14],另一项为期 7 年的前瞻性研究报道的相关风险相对较低(*HR* = 1.57,95% *CI*:1.42 ~1.73)[15],一项基于英国老龄化追踪调查的研究指出,与高握力的非肥胖个体相比,肥胖合并低握力的糖尿病发病风险明显增加(*HR* = 4.93,95% *CI*:2.85 ~8.53)[16]。这些研究均证实了动力性腹型肥胖是糖尿病发病的一个重要高危表型。

本研究中再次证实了单纯腹型肥胖(ND/AO)是糖尿病发生的独立危险因素,与 ND/NAO 组相比,ND/AO 组糖尿病发病风险显著增加了 71%(*HR* = 1.709),这一发现与既往研究结果一致[17-18]。其机制主要与腹型肥胖所致的内脏脂肪堆积有关,后者通过引发慢性低度炎症与脂毒性,干扰胰岛素信号通路,促进胰岛素抵抗,从而在糖尿病发病中发挥关键作用[19-20]。值得注意的是,单纯动力学障碍(D/NAO)并未显著增加糖尿病发病风险,与本研究结果相似,韩国一项前瞻性队列研究也显示绝对握力与糖尿病风险无显著关联,而相对握力(握力/体重)的降低则与风险上升有关[21]。这一方面可能与肌肉功能减退的负面影响在特定的代谢紊乱背景(如肥胖存在时)下才会有关;另一方面,也提示握力作为肌肉功能的代理指标,其下降可能反映了多种因素(如衰老、活动减少、营养不良等)的综合作用,其作为独立致病因素的效应可能相对较弱[22]。

然而,本研究发现,当腹型肥胖与握力下降并存,即表现为“动力性腹型肥胖(D/AO)”时,糖尿病发病

风险出现了更为急剧的升高,且显著高于单纯腹型肥胖,可能是因为它们通过不同的生理机制独立影响糖尿病的发生,在腹型肥胖所致的代谢紊乱基础上,肌肉功能减退可能通过多种途径导致糖尿病的发生。首先,骨骼肌是机体摄取和利用葡萄糖的最主要器官,握力下降所反映的肌肉质量减少和/或功能衰退,直接导致了葡萄糖处置场所的容量和效率降低[6,23];其次,肌肉是一个重要的内分泌器官,能分泌多种对代谢有益的肌因子(如鸢尾素),肌肉功能减退可能导致这些保护性因子的分泌减少,进一步削弱了对糖脂代谢的调控能力[24-26]。

本研究存在若干局限性。首先,本研究缺乏口服葡萄糖耐量试验(OGTT)2 h 血糖,可能导致部分糖尿病患者漏检;其次,饮食、体力活动以及糖尿病家族史等混杂因素未被完全排除,这些混杂因素可能影响血糖状态;此外,研究对象来自 CHARLS 数据库,以中老年为主,结论推广至其他人群时需谨慎。

综上,动力性腹型肥胖显著增加中国中老年人糖尿病发病风险,且风险高于单纯性腹型肥胖。联合评估肌肉功能与腹型肥胖有助于早期识别高危人群,为糖尿病防控提供新方向。

利益冲突声明　本研究不存在任何利益冲突

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评估。

利益冲突声明　本研究不存在任何利益冲突

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