

论著·临床研究

冠心病患者体成分与心肺适能的相关性

李 阳, 马 璐, 都屹泓, 许 莉, 陈菡芬, 邱训涵, 姜 萌[#], 卜 军[#]

上海交通大学医学院附属仁济医院心内科, 上海 200127

[摘要] **目的**·探究冠心病患者体成分与心肺适能 (cardiopulmonary fitness, CRF) 的相关性。**方法**·选取2022年10月至2023年6月于上海交通大学医学院附属仁济医院行择期经皮冠状动脉介入治疗的冠心病患者 (冠心病组) 以及健康体检者 (健康对照组)。所有受试者均在同一日接受心肺运动试验 (cardiopulmonary exercise testing, CPET) 测定CRF, 以及生物电阻抗分析 (bioelectrical impedance analysis, BIA) 测定身体成分。**结果**·共纳入冠心病患者191例、健康体检者188例。2组基线特征差异均无统计学意义。与健康对照组相比, 冠心病患者CRF指标均显著降低 (均 $P<0.05$); 在体成分指标中, 冠心病组躯干肌肉质量 (trunk muscle mass, TMM) 显著低于健康对照组 ($P<0.01$), 躯干脂肪质量 (trunk fat mass, TFM) 显著高于健康对照组 ($P<0.01$)。相关性分析显示, 冠心病组TMM ($R=0.538$)、下肢肌肉质量 (lower limbs muscle mass, LMM) ($R=0.754$)、下肢脂肪质量 (lower limbs fat mass, LFM) ($R=0.593$) 与每千克体质量峰值摄氧量 (VO_{2peak}/kg) 呈正相关 (均 $P<0.01$), TFM ($R=-0.563$) 与 VO_{2peak}/kg 呈负相关 ($P<0.01$)。其余体成分指标与 VO_{2peak}/kg 之间相关性均无统计学意义。依据 VO_{2peak}/kg 将冠心病患者分为低CRF组、中CRF组和高CRF组, 结果发现3组患者LMM、TMM、LFM、TFM之间差异均存在统计学意义 (均 $P<0.05$)。多元线性回归分析提示年龄、性别、TMM、TFM、LMM、LFM均是冠心病患者 VO_{2peak}/kg 的相关因素。冠心病患者的 VO_{2peak}/kg 随着TMM、LMM、LFM的升高而升高, 随着年龄和TFM的升高而下降, 女性相比于男性患者 VO_{2peak}/kg 更低。**结论**·冠心病患者的CRF显著低于健康人群, TFM更高, TMM更低; 在冠心病患者中, CRF与TFM呈负相关, 与TMM、LMM以及LFM呈正相关。

[关键词] 冠心病; 心肺适能; 体成分**[DOI]** 10.3969/j.issn.1674-8115.2024.01.008 **[中图分类号]** R541.1 **[文献标志码]** A

Correlation between body compositions and cardiopulmonary fitness in patients with coronary heart disease

Li Yang, MA Jun, DU Yihong, XU Li, CHEN Hanfen, QIU Xunhan, JIANG Meng[#], PU Jun[#]

Department of Cardiology, Renji Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai 200127, China

[Abstract] **Objective**·To explore the correlation between body compositions and cardiovascular fitness (CRF) in patients with coronary heart disease (CHD). **Methods**·The CHD patients (CHD group) who underwent elective percutaneous coronary intervention treatment at Renji Hospital, Shanghai Jiao Tong University School of Medicine from October 2022 to June 2023 as well as healthy people (control group) were selected. All the participants completed cardiopulmonary exercise testing (CPET) to determine CRF and bioelectrical impedance analysis (BIA) to determine body compositions on the same day. **Results**·A total of 191 patients with coronary heart disease and 188 healthy individuals were included. There was no statistically significant difference in baseline characteristics between the two groups. Compared with the control group, the CRF indicators of the CHD group were significantly reduced (all $P<0.05$). In terms of body composition indicators, the trunk muscle mass (TMM) of the CHD group was significantly lower than that of the control group ($P<0.01$), and the trunk fat mass (TFM) was significantly higher than that of the control group ($P<0.01$). Correlation analysis showed that TMM ($R=0.538$), lower limbs muscle mass (LMM) ($R=0.754$), and lower limbs fat mass (LFM) ($R=0.593$) were positively correlated with peak oxygen uptake per kilogram of bodyweight (VO_{2peak}/kg) in the

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[作者简介] 李 阳 (1994—), 男, 技师, 学士; 电子信箱: 619521677@qq.com。

[通信作者] 姜 萌, 电子信箱: jiangmeng90919@163.com。卜 军, 电子信箱: pujun310@hotmail.com。[#]为共同通信作者。

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[Corresponding Author] JIANG Meng, E-mail: jiangmen90919@163.com. PU Jun, E-mail: pujun310@hotmail.com. [#]Co-corresponding authors.



CHD group (all $P<0.01$), while TFM ($R=-0.563$) was negatively correlated with VO_{2peak}/kg ($P<0.01$). There was no statistically significant correlation between other body composition indicators and VO_{2peak}/kg . According to VO_{2peak}/kg , the CHD patients were divided into low CRF group, medium CRF group, and high CRF group. The results showed that there were statistically significant differences in LMM, TMM, LFM, and TFM among the three groups of patients (all $P<0.05$). Multiple linear regression analysis suggested that age, gender, TMM, TFM, LMM, and LFM were related factors of VO_{2peak}/kg in the patients with CHD. The VO_{2peak}/kg of CHD patients increased with the increase of TMM, LMM, and LFM and the decrease of age and TFM; the female patients had lower VO_{2peak}/kg compared to the males. **Conclusion** The CRF of CHD patients is significantly lower than that of the healthy population, with higher TFM and lower TMM; in the CHD patients, CRF is negatively correlated with TFM and positively correlated with TMM, LMM, and LFM.

[Key words] coronary heart disease (CHD); cardiopulmonary fitness (CRF); body composition

我国冠状动脉粥样硬化性心脏病（冠心病；coronary heart disease, CHD）发病率和死亡率呈现逐年迅速升高的趋势。肥胖和身体活动减少被列为第三和第四大心血管健康的危险因素，估计全国每3个人中就有1人为腹型肥胖^[1]。腹型肥胖是导致冠心病的主要危险因素之一，也是导致冠心病发展和死亡率上升的独立危险因素^[2]。同时，肌肉质量的衰减在冠心病患者中常见，大约有25%的冠心病患者存在肌肉质量和功能低下^[3]；进一步研究^[4]表明，肌肉质量是冠心病预后的重要影响因素，冠心病患者中低肌肉质量与全因死亡风险增高相关。

心肺适能（cardiopulmonary fitness, CRF）反映了人体摄入氧气并输送到线粒体，供给身体活动的综合能力。通过CRF的评估，可量化个体的整体运动功能，即包括肺通气和扩散能力、左右心室收缩和舒张功能、心室-动脉耦合、血管系统容纳和有效地把身体需要的氧气通过心血管系统进行输送的能力，以及肌肉摄取并利用所需的氧气和营养物质的能力^[5]。有研究^[6]表明，CRF是冠心病患者预后的重要预测因子，通过心肺运动试验（cardiopulmonary exercise testing, CPET）测量每千克体质量峰值摄氧量（ VO_{2peak}/kg ）可以直接反映人体的CRF情况，CRF越好的冠心病患者预后越好。美国心脏协会将CRF定为临床上的第五大生命体征，认为其与冠心病死亡率与发病率相关，并与全因死亡率和各种癌症风险相关^[5]。

由此可见，肥胖、肌肉质量以及CRF是冠心病预后的重要预测因子，但三者之间的相关性却缺乏研究。本研究旨在通过生物电阻抗分析（bioelectrical impedance analysis, BIA）测量冠心病患者的身体成分，包括上肢肌肉质量（upper limbs muscle mass, UMM）、下肢肌肉质量（lower limbs muscle mass, LMM）、躯干肌肉质量（trunk muscle mass, TMM），

以及上肢脂肪质量（upper limbs fat mass, UFM）、下肢脂肪质量（lower limbs fat mass, LFM）、躯干脂肪质量（trunk fat mass, TFM），同时通过CPET量化评估受试者的CRF，然后通过对冠心病患者身体成分与CRF的相关性分析，探讨相关指标在冠心病的一级预防以及二级预防中的重要性，探索对冠心病人群更好的治疗方案。

1 对象与方法

1.1 研究对象

选取2022年10月至2023年6月于上海交通大学医学院附属仁济医院心内科接受择期经皮冠状动脉介入治疗（percutaneous coronary intervention, PCI）的冠心病患者（冠心病组）以及健康体检者（健康对照组）。所有入选对象均在同一日先后接受实验室指标检测、体格检查、BIA和CPET。

1.1.1 冠心病患者入选标准 ① 年龄 ≥ 18 岁。② 经桡动脉冠脉造影显示至少1支冠状动脉 $\geq 70\%$ 管腔狭窄，并已接受完全再血管化治疗。③ 纽约心功能分级I~II级。④ 无不稳定型心绞痛、近期心肌梗死等CPET禁忌证。⑤ CPET结束时呼吸交换率（respiratory exchange ratio, RER） ≥ 1.10 ^[7]。⑥ 已应用GDMT（guideline-directed medical treatment）标准的冠心病药物治疗^[8]。⑦ 血压、血脂、血糖等均达到冠心病治疗指南^[9-10]推荐标准。⑧ CPET中无严重不良反应。

1.1.2 健康体检者入选标准 ① 年龄 ≥ 18 岁。② CPET结束时RER ≥ 1.10 ^[7]。③ 无CPET禁忌证。④ 既往无明确基础疾病诊断。⑤ 6个月内体检结果显示血压、血脂、血糖等均达到指南^[6]推荐标准。⑥ CPET中无严重不良反应。

1.1.3 受试者排除标准^[11] ① 限制运动的神经肌肉疾病。② 精神异常,不能配合者。③ 认知障碍不能配合者。④ 有起搏器、除颤器、人工肺、人工心脏者。⑤ 检测前5 d内接受过放射性检查或治疗。⑥ 孕妇。

1.2 资料收集

从上海市交通大学医学院附属仁济医院信息系统中导出研究对象各项资料。其中一般资料包括年龄、性别、吸烟史、饮酒史等,体格检查包括静息收缩压(resting systolic blood pressure, SBP_{rest})、静息舒张压(resting diastolic blood pressure, DBP_{rest})、体质量指数(body mass index, BMI),实验室指标包括空腹血糖(fasting blood glucose, FBG)、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),经桡动脉冠脉造影测定患者血管病变数量。

1.3 人体成分测定

所有对象均在行CPET检查当天完成身体成分的检测。正常饮食,排空大小便,穿轻便衣物,在无剧烈运动的情况下采用人体成分分析仪InBody770测定人体成分,记录UMM、LMM、TMM、UFM、LFM、TFM^[12]等指标。测定过程均由经过训练的专业人员引导和监督。

1.4 CPET

所有患者均在PCI术后2~7 d内完成CPET评定,健康体检者于同一日进行测试。采用冀德远健CPX-600心肺功能测试系统进行测试,受试者连接心电遥

测设备,并将座椅调整至合适高度。受试者先静坐3 min,然后在无负荷功率下以60 r/min的速度热身3 min,随后根据患者具体情况,选择10~25 W/min功率递增速率进行负荷运动。当患者自觉疲劳无法维持60 r/min的速度后将负荷功率递减到0 W进行整理运动2 min,最后停止运动观察3 min后结束测试^[13]。测试全程均由专业医师指导完成,并记录测试中的峰值摄氧量(VO_{2peak})、 VO_{2peak}/kg 、无氧阈下每千克体质量摄氧量(VO_{2AT}/kg)、氧脉搏(O_2P)、二氧化碳通气当量斜率(V_E/VCO_2 slope)、峰值心率(HR_{peak})、运动峰值收缩压(SBP_{peak})和舒张压(DBP_{peak})等指标。

1.5 统计学分析

采用SPSS 22.0统计软件进行数据处理。定量资料均进行正态性检验,符合正态分布的数据以 $\bar{x}\pm s$ 表示,2组间比较采用独立样本 t 检验;非正态分布的数据以 $M(Q_1, Q_2)$ 表示,2组间比较采用秩和检验。定性资料用频数(百分比)表示,2组间比较采用 χ^2 检验。身体成分与CRF的关系采用Spearman相关性分析,多因素分析采用多元线性回归分析。双侧检验, $P<0.05$ 表示差异有统计学意义。

2 结果

2.1 基本资料

共纳入379例受试者,其中健康体检人群188例,冠心病患者191例。所有冠心病患者均接受了完全再血管化治疗和GDMT冠心病药物治疗。临床基线数据详见表1,结果显示2组基线特征之间差异无统计学意义。

表1 冠心病组和健康对照组基线特征比较

Tab 1 Comparison of baseline characteristics between the CHD group and control group

Item	CHD group ($n=191$)	Control group ($n=188$)	P value
Age/year	63 (55, 68)	62 (57, 70)	0.477
BMI/($kg\cdot m^{-2}$)	24.1 (22.3, 27.1)	22.7 (21.6, 26.8)	0.187
Male/ $n(\%)$	162 (84.8)	147 (78.2)	0.133
History of smoking/ $n(\%)$	91 (47.6)	79 (42.0)	0.311
History of alcohol consumption/ $n(\%)$	119 (62.3)	104 (55.3)	0.112
FBG/($mmol\cdot L^{-1}$)	5.9 ± 1.3	5.1 ± 1.5	0.097
TC/($mmol\cdot L^{-1}$)	5.2 (4.7, 5.8)	4.9 (4.6, 5.5)	0.429
LDL-C/($mmol\cdot L^{-1}$)	3.1 (2.7, 3.6)	3.0 (2.6, 3.5)	0.152

Continued Tab

Item	CHD group (n=191)	Control group (n=188)	P value
HDL-C/(mmol·L ⁻¹)	1.3±0.4	1.2±0.2	0.187
SBP _{rest} /mmHg	122.2 (117.5, 132.9)	119.7 (115.1, 131.7)	0.075
DBP _{rest} /mmHg	71.2 (68.2, 78.9)	72.4 (67.3, 77.6)	0.368
Single vessel with lesions/n(%)	93 (48.7)	—	—
Multiple vessels with lesions/n(%)	98 (51.3)	—	—

Note: 1 mmHg=0.133 kPa.

2.2 体成分与CRF测定

2组人群各项CRF指标与体成分指标见表2。结果显示,健康人群与冠心病患者之间的VO_{2peak}/kg、VO_{2peak}、VO_{2AT}/kg、O₂P、V_E/VCO₂ slope、HR_{peak}差异

均有统计学意义(均P<0.05),健康人群的CRF均显著好于冠心病患者。在体成分指标中,冠心病患者的TMM显著低于健康人群,而TFM显著高于健康人群(均P<0.05)。

表2 冠心病组与健康对照组CRF和体成分比较

Tab 2 Comparison of CRF and body compositions between the CHD group and control group

Item	CHD group (n=191)	Control group (n=188)	P value
VO _{2peak} /kg/[mL·(kg·min) ⁻¹]	17.9±4.1	20.5±5.7	0.001
VO _{2AT} /kg/[mL·(kg·min) ⁻¹]	12.1±2.7	13.9±4.5	0.013
VO _{2peak} /(mL·min ⁻¹)	1 299.3±323.8	1 483.4±408.6	0.000
O ₂ P/(mL·beat ⁻¹)	10.3 (9.4, 12.1)	11.2 (9.9, 12.9)	0.025
V _E /VCO ₂ slope	26.2 (23.6, 29.3)	25.2 (23.4, 29.0)	0.002
HR _{peak} /(beat·min ⁻¹)	119.1±13.9	127.5±17.2	0.000
SBP _{peak} /mmHg	149.1 (138.5, 162.4)	152.3 (131.4, 167.5)	0.078
DBP _{peak} /mmHg	75.2 (68.5, 82.1)	75.1 (70.1, 85.4)	0.687
TMM/kg	22.5 (20.9, 25.2)	23.1 (19.4, 25.8)	0.007
TFM/kg	10.2±3.6	9.1±3.2	0.001
LMM/kg	14.7 (12.4, 15.9)	15.8 (14.3, 16.6)	0.222
LFM/kg	5.0 (4.3, 6.5)	5.4 (4.7, 6.3)	0.539
UMM/kg	5.8 (4.7, 6.4)	5.3 (4.5, 6.6)	0.617
UFM/kg	1.7±1.3	2.2±1.2	0.115

2.3 冠心病患者体成分与CRF的相关性

为进一步探究冠心病患者体成分与CRF之间的关系,将其体成分指标与CRF指标VO_{2peak}/kg进行相关性分析。结果(图1)显示:LMM(R=0.754)、TMM(R=0.538)、LFM(R=0.593)与VO_{2peak}/kg呈正相关(均P<0.01),TFM(R=-0.563)与VO_{2peak}/kg呈负相关(P<0.01);其余体成分指标与CRF之间均无相关性。

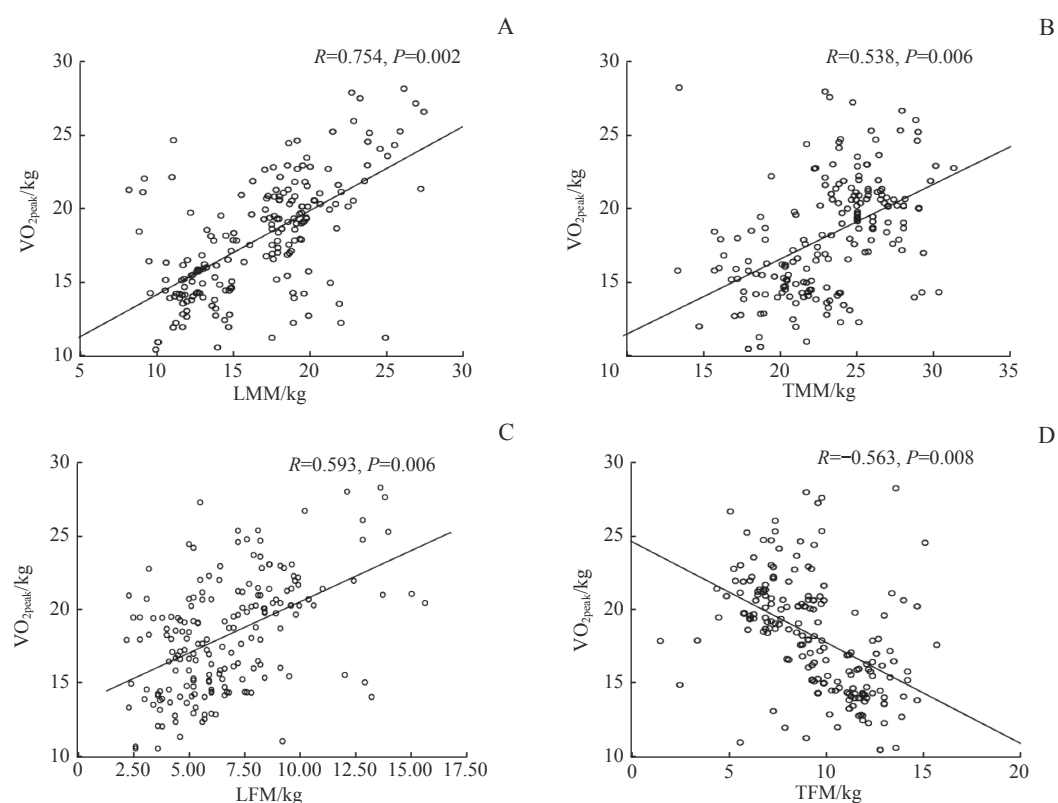
分别进行组间比较。结果(图2)显示:体成分指标中LMM(F=8.613, P=0.000)、TMM(F=2.364, P=0.007)、LFM(F=1.743, P=0.022)、TFM(F=2.774, P=0.003)在3组间差异均有统计学意义;TMM、LMM与LFM随患者CRF增强而增加,而TFM随患者CRF增强而减少;其余体成分指标均无组间差异。

2.4 冠心病患者不同CRF组间的体成分比较

为进一步比较不同CRF冠心病患者体成分之间的差别,依据患者CPET中测定的VO_{2peak}/kg将191例患者划分为低CRF组[<16.0 mL/(kg·min)]、中CRF组[16.0~20.0 mL/(kg·min)]、高CRF组[>20.0 mL/(kg·min)]^[7],对3组患者的体成分数据

2.5 冠心病患者体成分与CRF多因素分析

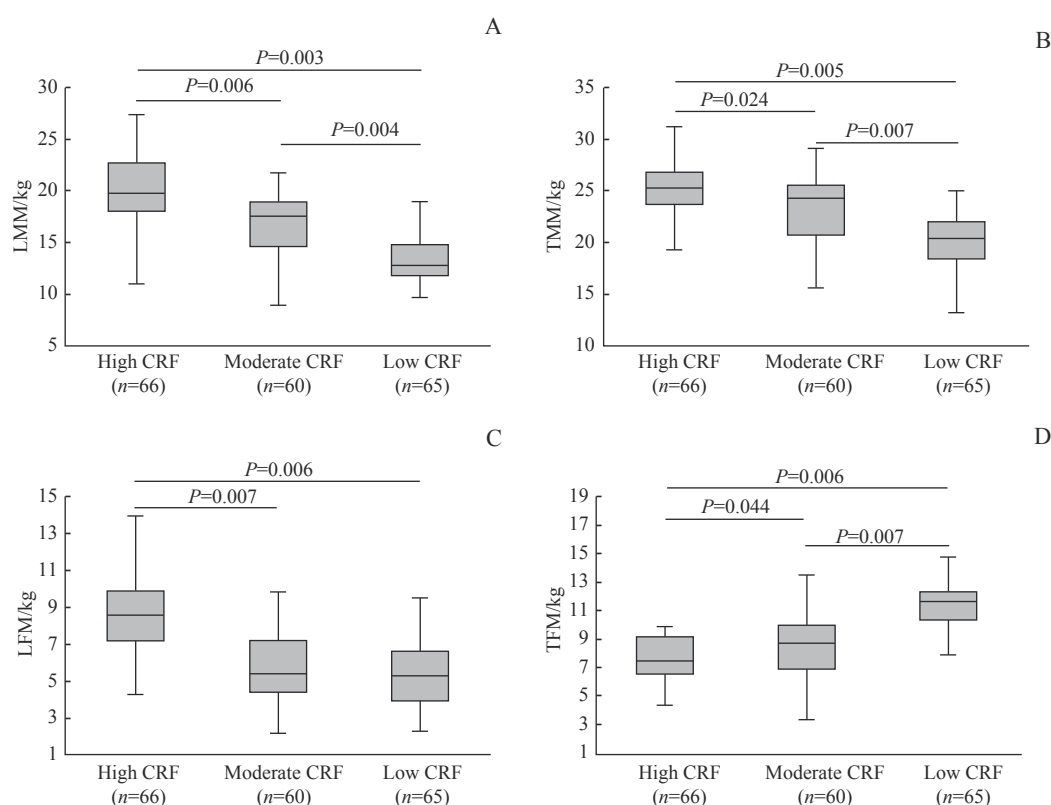
多因素线性回归分析将患者的基线特征及体成分指标纳入,结果显示年龄、性别、TMM、TFM、LMM、LFM均是冠心病患者VO_{2peak}/kg的相关因素。随着TMM、LMM、LFM的升高,冠心病患者的VO_{2peak}/kg升高;随着年龄和TFM的升高,冠心病患



Note: A. LMM. B. TMM. C. LFM. D. TFM.

图1 冠心病患者体成分与 VO_{2peak}/kg 相关性的散点图分析

Fig 1 Scatter plot analysis of the correlation between body compositions and VO_{2peak}/kg in CHD patients



Note: A. LMM. B. TMM. C. LFM. D. TFM.

图2 冠心病患者不同CRF组间体成分的比较

Fig 2 Comparison of body compositions among different CRF groups in CHD patients

者的 $\text{VO}_{2\text{peak}}/\text{kg}$ 下降,而女性相比于男性患者 $\text{VO}_{2\text{peak}}/\text{kg}$ 更低(表3)。

表3 冠心病患者 $\text{VO}_{2\text{peak}}/\text{kg}$ 相关因素的多因素线性回归分析

Tab 3 Multiple linear regression analysis of relative factors of $\text{VO}_{2\text{peak}}/\text{kg}$ in CHD patients

Item	B value	β value	t value	P value
Age	-0.166	-0.214	-1.745	0.041
Gender	2.949	0.985	2.990	0.003
LFM	-0.432	-0.178	-2.517	0.023
TMM	0.792	1.239	2.336	0.038
LMM	1.411	1.279	3.012	0.008
TFM	0.995	1.750	2.096	0.009

Note: $R^2=0.577$.

3 讨论

本研究通过分析冠心病患者以及健康人群的CRF以及TFM、TMM、LFM、LMM等指标,发现冠心病患者的CRF以及TMM均低于健康人群,TFM则高于健康人群。进一步分析冠心病患者中低、中、高CRF患者的体成分,发现高CRF的冠心病患者相比于中、低CRF冠心病患者有更高的TMM、LMM、LFM以及更低的TFM。

CRF可以通过 $\text{VO}_{2\text{peak}}/\text{kg}$ 较为直观地体现,CRF会受到年龄、性别的影响^[14],这在本研究中也得到证实。一项纳入了13 345名男性的研究发现峰值代谢当量(peak metabolic equivalent, MET_{peak} ;可由 $\text{VO}_{2\text{peak}}/\text{kg}$ 直接换算得到)每增加1个单位,全因死亡率和冠心病死亡率分别降低15%和19%^[15]。提升CRF可以显著降低冠心病的发生率^[16]。本研究中冠心病患者CRF显著低于健康人群,验证了CRF和冠心病之间的相关性。

BMI是最广泛使用的识别超重和肥胖的指标^[17]。但是BMI并不能说明肌肉和脂肪的分布情况,可能出现因肌肉质量过多导致BMI过高或者BMI正常但是内脏脂肪超标的情况。有研究^[18]表明,超重或者1级肥胖($25.0 \text{ kg/m}^2 \leq \text{BMI} < 29.9 \text{ kg/m}^2$)的人群和BMI正常人群相比死亡率没有差别,这一现象也被称为“肥胖悖论”,说明BMI在临床预测中的局限性。相比BMI,BIA更为精准,可以测量身体脂肪和肌肉的具体分布情况^[19]。本研究通过BIA测量冠心病患者,发现TFM与CRF呈负相关。先前已经有研究^[2]证明过多的TFM是冠心病不良预后的独立危险因素,内脏脂肪

的堆积会导致冠心病患者的活动能力的下降进而影响患者的CRF;本研究的结论也支持这一观点,进一步说明了减低冠心病患者内脏脂肪质量的重要性。

KATTA等^[20]研究显示,较高的TFM是冠心病发病的危险因素。本研究中冠心病患者的TFM高于健康人群,进一步证实了上述研究结果。因此,在CHD的一级预防中,需要对TFM予以高度重视,尽量降低高危人群TFM,以期达到预防心血管疾病的目的。

有研究表明肌肉质量可以作为冠心病预后的预测指标。肌肉质量的下降会导致外周对氧的摄取减少从而影响冠心病患者的CRF,肌肉质量与中高强度体力活动能力独立相关,缺乏体力活动会进一步导致CRF的下降^[4]。而年龄的增大也会导致肌肉量的下降,进而导致CRF的下降^[21]。而在本研究中,TMM以及LMM与CRF呈正相关。通过对冠心病患者增加力量干预可以增加患者的肌肉质量,进而提高CRF,改善冠心病患者的预后^[22]。

值得注意的是,本研究发现,LFM与CRF呈正相关。有研究^[23]表明,在肥胖人群中,较低的内脏脂肪和较高的LFM与较低的糖尿病以及冠心病发病率相关;另一项涵盖2 683名绝经后BMI正常女性的研究^[24]也得出了类似的结论。然而,尽管很多文献提到了LFM对于冠心病发病率的影响,却很少有文献提及LFM和冠心病患者预后的相关性。由于CRF是冠心病患者预后的重要因素^[6],而本研究证明了LFM和CRF的相关性,所以也间接说明了LFM和冠心病患者预后的关系,但其与冠心病患者预后的相关性仍需要进一步验证。

综上所述,相比健康人群,冠心病患者的CRF更差,TFM更高;在冠心病患者中,CRF与TFM呈负相关,与TMM、LMM以及LFM呈正相关。该结果提示在临床上需要重视对冠心病患者LFM以及TFM的评估,以及加强对LMM以及TMM的训练,以提高CRF,改善患者预后。

利益冲突声明/Conflict of Interests

所有作者声明不存在利益冲突。

All authors disclose no relevant conflict of interests.

伦理批准和知情同意/Ethics Approval and Patient Consent

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经签署知情同意书。

All experimental protocols in this study were reviewed and approved by Ethic Committee of Renji Hospital, Shanghai Jiao Tong University School of Medicine (Approval Letter No. KY2021-098-B), and all experimental protocols were carried out by following the guidelines of *Declaration of Helsinki* (revised in 2013). Consent letters have been signed by the research participants or their relatives.

作者贡献/Authors' Contributions

卜军和姜萌负责课题构思与设计, 李阳负责论文撰写, 马珺负责数据收集与论文修改, 都屹泓负责数据分析, 许莉和陈茜芬负责

数据校对, 邱训涵负责论文校对。所有作者均阅读并同意了最终稿件的提交。

The study was designed by PU Jun and JIANG Meng. The manuscript was drafted by LI Yang. The data were collected by MA Jun. The manuscript was revised by MA Jun. The data were analyzed by DU Yihong. The data were corrected by XU Li and CHEN Hanfen. The manuscript was proofread by QIU Xunhan. All the authors have read the last version of paper and consented for submission.

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