■表3　心大血管疾患リハビリテーション料算定の適応疾患

1. 急性心筋梗塞
2. 狭心症
3. 開心術後
4. 大血管疾患(大動脈解離，解離性大動脈瘤，大血管術後)
5. 慢性心不全(左室駆出率40%以下，最高酸素摂取量が基準値の80%以下またはBNPが80 pg/ml以上の状態のもの)
6. 末梢動脈閉塞性疾患であって，間欠性跛行を呈する状態のもの

■表4　心臓リハビリテーションにかかわる職種と役割

1. 心臓リハ医師あるいは循環器医師：施設の運営管理，運動処方，リハプログラム作成，安全管理，患者教育・啓発などについての責任者としての役割.
2. 専門的なトレーニングを受けた心臓リハ看護師：日常生活指導，疾患管理，安全管理を担当する.
3. 心臓リハのトレーニングを受けた理学療法士：患者の日常生活機能評価，ベッドサイドから在宅までの運動指導を担当する.
4. 運動指導専門家：主に安定した外来患者への運動指導を担当する.
5. 臨床検査技師：主に運動負荷試験を担当し，医師とともに運動処方を作成する.
6. 管理栄養士：栄養に関する個人・集団教育を担当する.
7. 薬剤師：薬剤，服薬に関する個人・集団教育を担当する.
8. 臨床心理士：精神・心理相談やストレス管理を担当する.

心臓リハビリテーションのスタッフと人材の育成

表4に心臓リハにかかわる職種と役割について示した.必ずしもすべての職種が必須ではなく，保険算定に必要なのは，専任の医師と専従・専任の看護師あるいは理学療法士である．しかしながら，少しでも質的な向上を望むのであれば，専属でなくても構わないので，臨床検査技師や管理栄養士，薬剤師に応援を頼むとよい．臨床検査技師にとっては，自分のかかわった運動負荷試験の結果がどのように評価され，それをもとにしてどのような運動処方が作成されるかは興味のあるところであるし，管理栄養士は栄養指導を通しての，患者管理の最も重要な分野のひとつである食行動への働きかけに長けている．また，管理栄養士は個人指導や集団講義などにも積極的にかかわってくれる．個人指導，集団講義とも保険算定が可能であるし，彼らにとっての実績にも直結するので比較的協力が得られやすい.

また，ある程度(20名程度)の患者数が確保できるのであれば，非常勤の運動指導専門家(健康運動指導士など)を雇うことが可能である．兎角，医療者だけで作成した運動プログラムは単調でつまらなくなる傾向がある．できれば運動指導者とともに，行動変容技法を意識した楽しいプログラム作成を心がけたい[4]．安全の確保のためには心臓リハ指導士の資格をもった運動指導者が好ましいが，なかなか探すのは難しい．インターネットを通じて募集を行うか，心臓リハ認定施設に見学に行った際に訊いてみるとよい．また，スタッフをどう育てるのかが問題であるが，日本心臓リハ学会では，平成20年度の重点事業として，学会認定心臓リハ研修施設の準備を行っている．平成20年1月からはその試行事業として榊原記念病院で研修を開始した(http://square.umin.ac.jp/jacr/sakakibara_cardiac_rehatre.html).

この研修制度は，実習を中心とした40時間の規定のプログラム(表5)にしたがって研修を行い，研修終了時には10症例についての症例報告をまとめる．研修教育責任者が研修者の研修状況ならびに出席状況と研修態度などの評価と研修報告書を学会に提出し，報告内容に問題がなければ，学会が心臓リハ指導士認定試験受験資格認定証を発行することになっている．正式には2008年秋から全国11施設で開始することになっているが，学会ホームページに募集要項などが掲示されるので注意してみてほしい.

研修希望者は職種もさまざまであり，その実力や目的も異なるため的を絞りにくい難しさがあり，研修者を受ける側も日常業務のなかでの指導となるため必ずしも十分な研修とはいえないが，あらかじめ心臓リハスキルアップセミナーや心肺運動負荷試験セミナーなどの関連講習会への出席や，各種ガイドライン，参考図書などで十分に予習したうえで，きちんとした目的意識をもって参加してほしい．5日間40時間の研修のなかで，

■表5　学会認定心臓リハ研修カリキュラム(試行版)

	1日目(月)	2日目(火)	3日目(水)	4日目(木)	5日目(金)
午前	9：00～ オリエンテーション 担当：看護師 外来リハ見学	9：00～ ICU，病棟リハ見学 担当：理学療法士 11：00～ スタッフミーティング参加	9：00～ 外来リハの実践 (11：00～講義) 担当 午前　看護師 午後　運動指導士	9：00～ 症例報告書作成	9：00～ 担当：理学療法士
午後	リハ開始時診察，運動処方，説明の見学 担当：医師	外来リハの実践 担当：看護師		14：00～ CPXの見学 担当：検査技師	14：00～15：00 リハ回診見学 15：15～ 患者向け講義参加
	～17：00	～17：00	～17：00	～17：00	～17：00

10症例のケースカード作成は決して簡単ではない．また，40時間の研修は必ずしも十分ではなく，可能であればこのような短期研修ではなく，3カ月以上の長期研修を検討してほしい．

文献

1) 長山雅俊，伊東春樹：心疾患のリハビリテーション　歴史的展開．総合リハ 35：7-14, 2007.
2) 長山雅俊，伊東春樹：平成18年度診療報酬改定について．心臓リハ 12：177-180, 2007.
3) 長山雅俊，齊藤正和：重症心不全(NYHA Ⅲ)の運動療法．臨床リハ 16：1037-1044, 2007.
4) 長山雅俊：行動変容技法を取り入れた心臓リハビリテーション．虚血性心疾患診療のコツと落とし穴(上松瀬勝男編)，中山書店，2003, pp 192-193.

特集

慢性心不全の予防と治療のup-date — ここが知りたい —

3

心不全治療としてのリハビリテーション

長山 雅俊

榊原記念病院 循環器内科

はじめに

慢性心不全に対する運動療法は，息切れなどの自覚症状や運動耐容能を改善することが証明され，平成18年度の診療報酬改定では，心大血管疾患リハビリテーション（以下心リハ）の適応疾患として慢性心不全が認められるようになった。しかしながら心不全にも様々な病態があり，特に重症例への適用に関しては十分な注意が必要である。また，心リハの介入の時期についても，心不全入院患者に対する早期からの理学療法介入の有用性が報告されるようになるなど[1]，亜急性期以後の患者管理の方法が変化してきている。また，レジスタンストレーニング[2,3]を有効に取り入れることにより，更なる効果が期待できるとされるが，その実際的な方法や重症例に対する適応などについては十分解明されていない。

運動療法の適応と禁忌

低心機能症例に運動療法を行う場合には，その導入時において運動療法の適応や禁忌について改めて評価し，厳密に対応しなくてはならない。**表1**には2001年に発表されたヨーロッパ心臓病学会の慢性心不全に対する運動療法の適応と禁忌，**表2**には運動療法を中止または変更する基準について示した[4]。そして可能な限り，心肺運動負荷試験による科学的根拠に基づいた運動処方を行うべきである。運動療法における基本的な運動強度は，残存心機能に過度の負担を掛けないレベルで全身機能を改善させることのできる運動強度であり，嫌気性代謝閾値（Anaerobic threshold: AT）レベル相当または以下の運動強度である[5]。心機能低下例では，ATレベル以上の運動強度では，左室駆出率の低下をきたす例が多い[6]ことから，低心機能症例ではATレベル以下の運動強度から開始し，経過を見ながら負荷強度を漸増することが望ましい。しかしながら急性期治療を脱したばかりの患者や重症例では必ずしも運動負荷試験が可能な患者ばかりではなく，その場合は心電図や血圧をモニターしながら，低強度による様々な運動療法を工夫することになる。

運動療法の効果

1）自覚症状に対する効果

運動療法が慢性心不全における労作時息切れや易疲労感を良く改善させる[7-9]ことはよく知られているが，中枢効果よりも末梢効果がその主体と考えられている。

2）運動耐容能に対する効果

慢性心不全においても運動療法が運動耐容能を改善させることが報告されている。特に心肺運動負荷試験で得られる最高酸素摂取量（peak $\dot{V}O_2$）やATが改善したという報告が多い[10,11]。

3）心機能に対する効果

慢性心不全に対する運動療法の中枢効果として，運動時の肺動脈楔入圧を上げることなしに，運動時の心拍出量を増やすことが報告されている[12]。この効果は心臓そのものに対する効果というよりも，運動療法の効果としての血管拡張能改善による後負荷の低下や心拍血圧反応の改善，筋ポンプ機能の向上などによる二次的な効果と考えられている。

4）呼吸機能に対する効果

慢性心不全患者では，浅くて速い換気様式を示すことが特徴である。運動療法はこの呼吸パターンを改善させ，その改善度は自覚症状と良く一致する。

5）末梢循環に対する効果

表1　慢性心不全患者に対する運動療法の適応と相対・絶対禁忌(ESC Working group)[4]

【適応】

安定期にあるコントロールされたNYHA II～IIIの慢性心不全患者
以下の状態で少なくとも2週間経過していること

臨床所見

1. 1週間以上利尿薬の増量がなくても体重が安定している。
2. うっ血の症状がない（起坐呼吸，浮腫，腹水，頸静脈圧>8cmH_2O）
3. 収縮期血圧≧80mmHgで，起立性低血圧なし，脈圧/収縮期血圧>20%
4. 50bpm<心拍数≦100bpmで安定している。
5. 狭心症状なし。
6. 不整脈なし，若しくは頻度が少ない。（ICD作動≦1回/月）
7. 息切れすることなく更衣が可能
8. 100～200m快適に歩ける。

検査所見

1. Cr<2.5mg/dL，BUN<50mg/dL
2. 血清Na>137mRq/L
3. peak $\dot{V}O_2$≧10～12mL/kg/min

【相対禁忌】

1. 最近1～3日間に体重1.8kg以上増加
2. 持続的または間欠的ドブタミン治療中
3. 運動時収縮期血圧低下
4. NYHA class IV
5. 安静時または労作時重症不整脈
6. 臥位安静時心拍数100/分以上
7. 既存疾患の状態

【絶対禁忌】

1. 最近3～5日間で安静時，労作時の運動耐容能または息切れの進行性の増悪
2. 低強度での明らかな虚血(2Mets以下，約50W)
3. コントロール不良の糖尿病
4. 急性全身疾患または感染症
5. 最近の塞栓症
6. 血栓性静脈炎
7. 活動性の心膜炎または心筋炎
8. 中等度から高度大動脈狭窄
9. 外科治療を必要とする逆流性弁膜症
10. 3週間以内の心筋梗塞
11. 新たに発症した心房細動

心不全における末梢循環異常として，交感神経系とレニン-アンジオテンシン系を中心とした神経体液性因子の活性化により，末梢の抵抗血管が収縮し，皮膚や筋肉への末梢循環が低下する。さらに末梢血管の血管内皮機能が低下し，拡張機能障害に陥っているとされるが，運動療法は内皮機能の改善から血管拡張反応を改善する効果があることが報告されている[13]。

6）神経体液性因子に対する効果

慢性心不全に伴う自律神経バランスの異常は，過度の交感神経緊張と副交感神経機能の低下という特徴を持つ。また，交感神経刺激に対する心筋の反応性も低下し，安静時の心拍数が高く，運動による心拍増加反応が悪い（chronotropic incompetence）[14]という現象が認められる。運動療法は減弱した副交感神経機能を改善させることにより，安静時の心拍数を減少させ[15]，運動による心拍増加反応を改善することが報告されている[16]。一方，慢性心不全の病態の進行に，各種炎症マーカーの関与が指摘されている。運動療法はCRPやTNF-α，interleukin-6等の炎症性サイトカインやアポトーシスの指標である可溶性FASを減少させることが報告されている[17]。

7）骨格筋に対する効果

慢性心不全ではディコンディショニングによる骨格筋の廃用性変化ばかりでなく，有気的代謝が主体のtype I線維やtype IIa線維の減少と無気的代謝主体のtype II b線維の相対的増加や骨格筋運動での代謝物（乳酸，アデノシン，H^+，K^+など）からの刺激を中枢に伝える受容体（エルゴレセプター）の過剰反応が生じることが報告されている。運動療法は筋線維の割合を正常化し，骨格筋代謝を改善することにより，易疲労などの自覚症状や運動耐容能を改善することが報告されている[18]。

8）精神・心理的効果

運動療法が心不全患者の不安，抑うつを軽減しQOLを改善するという報告は多い[9,19,20]。

9）予後に対する効果

生命予後や再入院率に関する長期予後についての検討については，Belardinelliらが行った無作為割り付

表2　運動療法を中止または変更する基準（ESC Working group）[4)]

1．著明な息切れまたは倦怠感(Borg scale 14以上)
2．運動中呼吸数40/分以上
3．III音または肺ラ音の出現
4．肺ラ音の増強
5．II音肺動脈成分の増強
6．脈圧の減少（収縮期，拡張期の差が10mmHg未満）
7．運動中の血圧の低下（10mmHg以上）
8．運動中による上室性または心室性期外収縮増加
9．発汗，蒼白または意識混濁

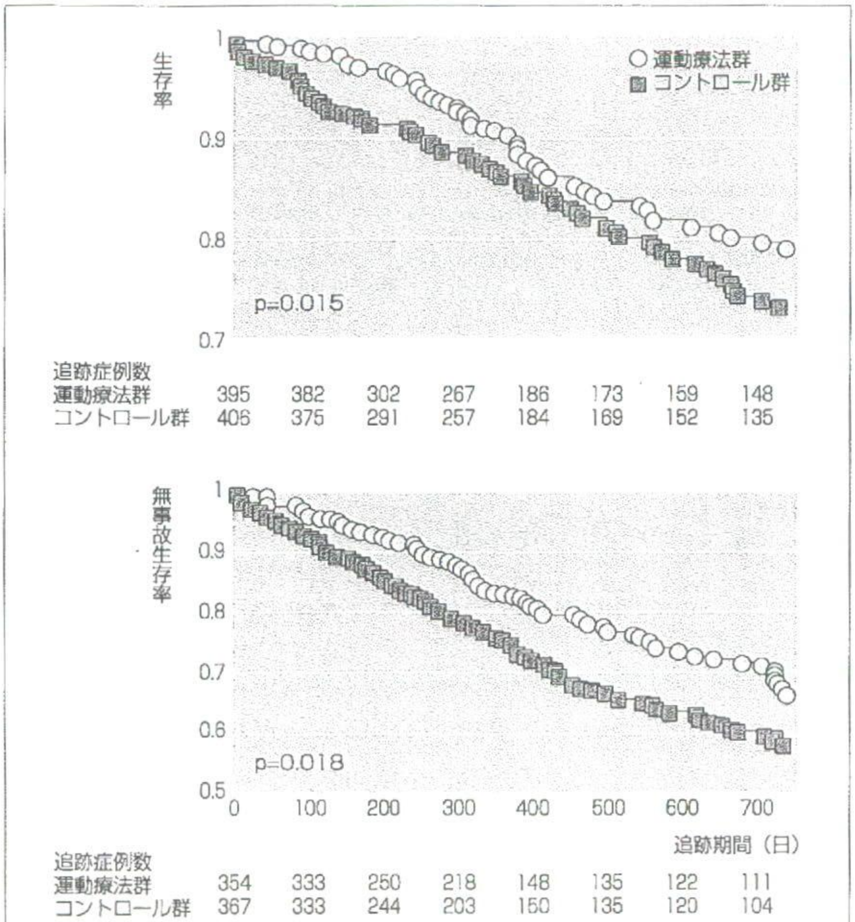

図1　心不全の運動療法の長期予後に対する効果（ExTraMATCH研究）[21)]

け試験[9)]によるものが重要である。彼らは，99例の安定期心不全患者を対象に運動療法群と非運動療法群とに無作為割り付けし，運動療法群には14ヵ月間にわたりpeak $\dot{V}O_2$の60％の運動強度で週に2～3回のトレーニングを行い，平均約3年4ヵ月間追跡調査した。その結果，左室駆出率や左室径には変化が見られなかったが，peak $\dot{V}O_2$，心筋の^{201}Tl摂取率，心不全スコアーは，いずれも運動療法群でのみ改善した。また，運動療法群では，全死亡率は42％の減少，心臓死は22.8％減少，心不全による入院も19％減少し，運動療法は明らかに生命予後を改善したと報告している。さらに，2004年に発表された9編メタ解析であるExTraMATCH研究（**図1**）[21)]では，比較的重症の801症例（NYHA 2.6度，EF 28％，peak $\dot{V}O_2$ 15.4mL/min/kg）を対象とした研究で，慢性心不全に対する運動療法は，生存率（$p=0.015$），無事故生存率（$p=0.018$）ともに運動療法群が有意に良好であり，安全でかつ生命予後を改善することを示した。

心臓リハビリテーションの実際 —低心機能症例へのphase II心リハの効果と安全性—

当院では2006年1月～12月の1年間に392例のphase IIプログラム新規参加者がいたが，左室駆出率40％未満の低心機能症例は69例（17.6％），年齢64±13歳であった。疾患の内訳は心筋梗塞後や弁膜疾患，拡張型心筋症など様々であったが，心機能は左室駆出率で31.6±6.6％であった。このような背景の低心機能症例に対し，週1～3回3ヵ月間の通院による監視型運動療法を施行した。心リハを開始するに当たり，病歴を整理し，心大血管疾患リハビリテーション実施計画書を作成，前述の適応を厳密に守り，十分なインフォームドコンセントの上に導入した。そして，心リハでの通院時には，看護師による問診やバイタルチェックを行い，問題がある場合には必ずリハ担当医師が診察を行った後，問題がない場合にのみ心リハを実施した。心リハの効果は，3ヵ月間でAT（mL/min/kg）は10.9から12.4へと＋10.9％の増加，peak $\dot{V}O_2$（mL/min/kg）も15.8から18.7へと＋17.5％の増加，VE-VCO_2 slopeは，34.5から31.3と有意に低下し，運動耐容能の改善と運動時換気効率の

有意な改善を認めた。また，血漿BNP（pg/mL）は474から286と有意な低下を認めている。そしてこれらの改善度は，左室駆出率40％以上の心機能の保たれた群に比べて，同等の効果であった。また，SF-36での健康関連QOLでも身体的役割機能，精神的役割機能の改善を認めている。安全性の検討では，病院での運動療法実施中には1例も心事故は認めなかったものの，3カ月間の心リハ期間中でみると，約1割の症例で心不全の悪化や心房細動などの不整脈により，心リハの中断や運動処方の下方修正を余儀なくされていた。心リハ中断群では，左室駆出率27.9±7.0％と中断する必要のなかった群32.6±6.1％に対し有意に左室収縮力は低かった（p=0.01）。このように低心機能症例に対する運動療法は，従来の報告どおり運動耐容能やQOL改善に有効であることが示されたが，ある一定の率，特に左室駆出率30％未満では，心リハ期間中に何らかの心事故を起こす可能性があることを十分注意する必要があることが分かる。

おわりに

以上，慢性心不全における運動療法の効果と実際について解説したが，わが国における心臓リハビリテーション施設はまだまだ少なく，低心機能症例に対する運動療法の経験も少ないのが実状である。適切な適応と管理基準を守った上での運動療法は，患者の運動耐容能の改善からQOLを改善し，日常生活上の余力を獲得することにより予後改善につながる。しかしながら，どの治療法でもそうであるように治療の限界は存在し，運動療法施行期間中に悪化する症例も少なからず存在する。低心機能症例に運動療法を行う場合には，それらを知った上で，運動療法のみならず，処方内容調整を含めた医学管理を同時に行っていくことが必要である。

文　献

1) 高橋哲也・他：心臓リハビリテーション遅延例への理学療法的アプローチ．心臓リハビリテーション．6, 2001, 62-65.
2) Pollock ML, et al: AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. Circulation 2000;101: 828-833.
3) 長山雅俊・他：心臓リハビリテーションにおけるレジスタンストレーニング．心臓リハビリテーション．10, 2005, 198-202.
4) Working Group on Cardiac Rehabilitation & Exercise Physiology and Working Group on Heart Failure of the European Society of Cardiology. Recommendations for exercise training in chronic heart failure patients. Eur Heart J 2001;22:125-35.
5) 伊東春樹：Anaerobic threshold(AT)．水野康，他編，循環器負荷試験法，診断と治療社，東京，1991，pp256-294.
6) Koike A, et al: Detecting abnormalities in left ventricular function during exercise by respiratory measurement. Circulation 1989;80: 1737-46.
7) Sullivan MJ, et al: Exercise training in patients with severe left ventricular dysfunction. Hemodynamic and metabolic effects. Circulation 1988;78:506-15.
8) Coats AJ, et al: Effects of physical training in chronic heart failure. Lancet 1990;335:63-6.
9) Belardinelli R, et al: Randomized, controlled trial of long-term moderate exercise training in chronic heart failure: effects on functional capacity, quality of life, and clinical outcome. Circulation 1999;99:1173-82.
10) Belardinelli R, et al: Exercise training improves left ventricular diastolic filling in patients with dilated cardiomyopathy. Clinical and prognostic implications. Circulation 1995;91:2775-84.
11) Itoh H, et al: Exercise training after cardiac surgery. Exercise gas exchange in heart disease. Ed by Wasserman K Futura Pub Co. New York, 1996, pp229-244.
12) Dubach P, et al: Effect of high intensity exercise training on central hemodynamic responses to exercise in men with reduced left ventricular function. J Am Coll Cardiol 1997;29:1591-8.
13) Akashi Y, et al: Short-term physical training improves vasodilatory capacity in cardiac patients. Jpn Heart J 43;2002:13-24.
14) Colucci WS, et al: Impaired chronotropic response to exercise in patients with congestive heart failure. Role of postsynaptic beta-adrenergic desensitization. Circulation 1989; 80:314-23.
15) Coats AJ, et al: Controlled trial of physical training in chronic heart failure. Exercise performance, hemodynamics, ventilation, and autonomic function. Circulation 1992;85: 2119-31.
16) Keteyian SJ, et al: Effects of exercise training on chronotropic incompetence in patients with heart failure. Am Heart J 1999;138:233-40.
17) Adamopoulos S, et al: Physical training modulates proinflammatory cytokines and the soluble Fas/soluble Fas ligand system in patients with chronic heart failure. J Am Coll Cardiol 2002;39:653-63.
18) Adamopoulos S, et al: Physical training improves skeletal muscle metabolism in patients with chronic heart failure. J Am Coll Cardiol 1993;21:1101-6.
19) Giannuzzi P, et al: ELVD-CHF Study Group, Antiremodeling effect of long-term exercise training in patients with stable chronic heart failure: results of the Exercise in Left Ventricular Dysfunction and Chronic Heart Failure (ELVD-CHF) Trial. Circulation 2003;108:554-9.
20) Austin J, et al: Randomised controlled trial of cardiac rehabilitation in elderly patients with heart failure. Eur J Heart Fail 2005;7:411-7.
21) Piepoli MF, et al: ExTraMATCH Collaborative. Exercise training meta-analysis of trials in patients with chronic heart failure (ExTraMATCH). BMJ 2004;328:189-92.

原　著

心疾患患者における運動耐容能に関わる運動機能指標の相互関係について―高齢群および壮年群での検討―

森尾裕志*1，井澤和大*1，渡辺　敏*1，平木幸治*1，田中彩乃*1，笠原酉介*1，
武市尚也*2，長田尚彦*3，大宮一人*3，三宅良彦*3，川間健之介*4

*1聖マリアンナ医科大学病院 リハビリテーション部，*2川崎市立多摩病院 リハビリテーション科，
*3聖マリアンナ医科大学 循環器内科，*4筑波大学大学院 人間総合科学研究科

抄　録

【目　的】運動耐容能に関わる運動機能指標の相互関係を明らかにし，高齢群と壮年群での適合モデルを検討することで，年齢を考慮した心臓リハビリテーション（CR）の方策について提案することである．

【方　法】対象は当院ハートセンターにおいて急性期CRプログラムを終了，かつ発症または術後1ヵ月時点において運動耐容能（最高酸素摂取量：Anaerobic Threshold）と運動機能指標〔筋力（握力，膝伸展筋力），バランス能力（Modified Functional Reach Test：片脚立位時間），歩行能力（歩行速度，歩幅）〕の測定を施行した108例（平均年齢62.8歳）である．これらの対象者を高齢群（57例）と壮年群（51例）の二群に選別し，筋力，バランス能力，歩行能力が運動耐容能に影響するという因果モデルについて共分散構造分析を行った．

【結　果】運動耐容能に関わる因果モデルは，高齢群と壮年群で異なることが確認された．壮年群においては，「筋力」の増減要因が「運動耐容能」に直接的に関わるのに対し，高齢群の場合，「バランス能力」と「筋力」が，「歩行能力」を介して「運動耐容能」に間接的に影響することが明らかとなった．

【考　察】高齢群では，筋力やバランス能力の低下によって歩行能力や運動耐容能が制限される可能性があることから，高齢群のCRプログラム施行に際しては，筋力，バランス能力の把握とともにその維持増強が重要であると考えられた．

〔心臓リハビリテーション（JJCR） 13（2）：299-303，2008〕

Key words：高齢者，最高酸素摂取量，歩行能力，バランス能力，筋力

緒　言

心臓リハビリテーション（CR）の予期しうる効果として，運動耐容能の改善，症状軽減，健康関連QOLの向上等が挙げられている[1]．なかでも運動耐容能を推測するための指標である最高酸素摂取量（Peak $\dot{V}O_2$）は，生命予後の独立予測因子の一つである[2]．したがって，運動耐容能をいかに改善できるかがCRを施行するうえでの一つの課題となる．

近年，社会的な背景として心大血管疾患患者の著しい高齢化が報告されているが[3]，一般的に加齢に伴い骨格筋筋力[4]やバランス能力，歩行能力[5]，および運動耐容能[6]などの運動機能は低下する．そのため，高齢心大血管冠疾患患者に対するCRの一方策として，運動耐容能を向上するためのプログラムの検討が必要である．

そこで，本研究は運動耐容能に関わる運動機能指標の相互関係を明らかにし，高齢群と壮年群での適合モデルを検討することで，年齢を考慮したCRの方策について提案することを目的とした．

方　法

1．倫理的配慮

本研究を実施する際には，当大学生命倫理委員会の承認を得た．本研究への参加に際し，事前に患者に研究の趣旨，内容および調査結果の取扱い等に関して説明し同意を得た．また調査実施に際しては，患者に対する負担を可能なかぎり抑えるように配慮した．

2．対　象

対象は，2005年10月～2007年9月の間に，聖マリアンナ医科大学病院ハートセンターにおいて急性心筋梗塞発

症または心臓外科手術後に，急性期CRプログラムを終了，かつ発症または術後1ヵ月時点において心肺運動負荷試験(CPX)，ならびに以下の測定項目の測定に際し同意が得られた心疾患患者108例(平均年齢62.8歳)である．主たる疾病の内訳は虚血性心疾患74例（68.5%），冠状動脈バイパス術24例(22.2%)，弁置換術後10例(9.3%)であった．これらの対象者を高齢群(65歳以上)と壮年群(35～64歳)の二群に選別し，比較，検討した．

3．調査・測定項目

a） 基礎疾患および属性に関する情報

基礎疾患および属性に関する情報は診療記録より調査した．その内容は年齢，性別，左室駆出率（LVEF）である．身長および体重はCPX時に測定し，Body Mass Index（BMI）を算出した．

b） 運動耐容能

運動耐容能の指標は，Peak $\dot{V}O_2$とAnaerobic Threshold（$\dot{V}O_2$ at AT）とし，これらはCPXより求めた．運動負荷にはトレッドミルによる当院のランプ負荷プロトコールを用い[7]，呼気ガスの測定にはミナト医科学社製aero monitor 300Sにて行った[8]．なお，後述する運動機能指標との関連を明確にするため，運動負荷試験を心筋虚血や不整脈など不良な心血管反応にて終了した症例，呼吸器疾患を有する症例については対象から除外した．

c） 筋　力

筋力の指標は，握力と等尺性膝伸展筋力を採用した．握力は，Jamar® Hand Dynamometer-5030J1(Sammons Preston，Bolingbrook）を用いた．開始肢位は，坐位，肘屈曲90°，前腕中間位にて握力を左右2回測定し，その最高値の左右の平均値（kgf）を検者が算出した[8]．

同様に，下肢筋力の指標として等尺性膝伸展筋力を採用し，測定機器はアニマ社製Hand Held Dynamometerを用いた．測定方法は，先行研究[4,9]に準じて施行し，左右の最大値の平均（kgf）を体重で除した値（kgf/体重）を膝伸展筋力として算出した．筋力測定中のリスク管理としては，心電図モニターにて心電図，心拍数を監視し，終了直後には聴診法によって血圧測定を行った．

d） バランス能力

バランス能力の指標は，前方リーチ距離と片脚立位時間を採用した．前方リーチ距離（cm）は，Modified Functional Reach Test（M-FRT）[10,11]にて測定し，測定方法は先行研究[10,11]に準じて施行した．片脚立位時間は開眼にて上肢で手すりを保持した姿勢から一側の下肢を静かに挙上し，さらに両上肢は手すりから離し，検者はできるだけ片足で立ち続けるよう指示した．どちらかの上肢や骨盤が手すりに触れた場合，あるいは支持側以外の下肢が床に触れるまでの時間(秒)を測定した．測定時間の上限は30秒とした[12]．なお，それぞれの測定は十分な練習を施した後，2回実施し，最高値を採用した．

e） 歩行能力

10m歩行速度は助走路を設け，計測開始地点のテープを越えた接床から10m先のテープを越えた接床までの時間と歩数を測定した．歩行はできるだけ速く歩くよう指導し，2回の計測のうち時間の短い記録を採用した．そして，最大歩行速度(m/秒)[13]と歩幅(cm)を算出した．

4．統計解析

Peak $\dot{V}O_2$，$\dot{V}O_2$ at AT，握力，膝伸展筋力，M-FRT，片脚立位時間，歩行速度，歩幅の各変数間の関連性を検討するために，ピアソンの相関係数を求めた．なお，統計学的判定の基準は5%とした．また，運動耐容能に対して筋力，バランス能力，歩行能力が関わるという仮説モデルを検証するため，多重指標モデルを用いた共分散構造分析[14,15]を行った．仮説モデルは高齢群と壮年群でそれぞれ設定し，モデル適合度にはGFI，AGFI，RMR，CF，NFI，RMSEAを用いた．モデル修正は，パス係数の有意性，修正指数（Amos 5.0J）に基づいて行い，モデル修正に伴うモデル適合度の変化はAICによって確認した．GFIおよびAGFIは，推定された共分散構造分析と標本分散行列とのくい違いの程度により適合度を示し，これらの値が1に近いときに良い当てはまりを示す．また，RMRの値は0に近いほど良い当てはまりを示す．回帰分析では，GFIは重相関係数，AGFIは自由度調整済みの重相関係数に対応する．CFIおよびNFIは，モデルが独立モデルと飽和モデルとを結ぶ直線上の位置により適合度を示し，1に近いときに良い当てはまりを示す．RMSEAは，モデルの複雑さによる見かけ上の適合度の上昇を調整する適合度指標の一つである．0.08以下であれば適合度が高いとされており，0.10以上であればモデルを採択すべきではないとされている．AICは相対的なモデルの良さを示す指標であり，モデル間の比較に適している[5,14,15]．以上の統計解析には，アプリケーションソフトウェアAmos 5.0JおよびSPSS 12.0Jを用いた．

結　果

表1に高齢群（57例）と壮年群（51例）の対象者の属性と各指標の平均値を示した．高齢群では壮年群に比べ

表１　対象の属性および運動機能指標

	高齢群	壮年群	p 値
症例数（男性/女性）	57(38/19)	51(45/6)	
年齢（歳）	71.1±5.0	53.5±9.2	＜0.001
BMI（kg/m^2）	22.5±3.0	24.3±3.2	0.003
LVEF（%）	58.2±13.9	52.6±14.7	0.085
運動機能指標			
Peak $\dot{V}O_2$（mL/kg/min）	20.9±4.8	25.4±5.6	＜0.001
$\dot{V}O_2$ at AT（mL/kg/min）	16.9±3.6	18.6±4.5	0.031
握力（kgf）	34.1±10.4	41.8±8.2	＜0.001
膝伸展筋力（kgf/ 体重）	0.57±0.15	0.70±0.17	＜0.001
M-FRT（cm）	37.3±4.9	42.2±4.9	＜0.001
片脚立位時間（秒）	24.5±8.4	29.7±1.6	＜0.001
歩行速度（m/秒）	1.9±0.4	2.1±0.4	0.008
歩幅（cm）	77.7±10.6	84.8±9.2	＜0.001
基礎疾患（例）			
心筋梗塞	37	37	
冠動脈バイパス術後	14	10	
弁置換術後	6	4	

BMI：body mass index, LVEF：left ventricular ejection fraction, $\dot{V}O_2$：oxygen uptake, M-FRT：modified functional reach test, 平均値±標準偏差

表２　高齢群と壮年群における各測定指標間の相関係数

【高齢群】

	年齢	Peak $\dot{V}O_2$	$\dot{V}O_2$ at AT	握力	膝伸展筋力	M-FRT	片脚立位	歩行速度
Peak $\dot{V}O_2$	−0.43**							
$\dot{V}O_2$ at AT	−0.33*	0.90**						
握力	−0.35**	0.48**	0.33*					
膝伸展筋力	−0.23	0.36**	0.31*	0.68**				
M-FRT	−0.30*	0.37**	0.13	0.58**	0.35**			
片脚立位時間	−0.44**	0.32*	0.32*	0.45**	0.35**	0.28*		
歩行速度	−0.38**	0.42**	0.35**	0.61**	0.59**	0.48**	0.41**	
歩幅	−0.34**	0.48**	0.41**	0.71**	0.58**	0.58**	0.50**	0.81**

*p ＜0.05, **p ＜0.01

【壮年群】

	年齢	Peak $\dot{V}O_2$	$\dot{V}O_2$ at AT	握力	膝伸展筋力	M-FRT	片脚立位	歩行速度
Peak $\dot{V}O_2$	−0.40**							
$\dot{V}O_2$ at AT	−0.28*	0.86**						
握力	−0.28*	0.31*	0.22					
膝伸展筋力	−0.06	0.52**	0.32*	0.40**				
M-FRT	−0.27	0.24	0.18	0.23	0.20			
片脚立位時間	−0.07	0.13	0.12	−0.03	0.16	0.04		
歩行速度	−0.15	0.28*	0.27	0.17	0.25	0.21	0.06	
歩幅	−0.19	0.38**	0.43**	0.27	0.30*	0.29*	0.13	0.77**

*p ＜0.05, **p ＜0.01

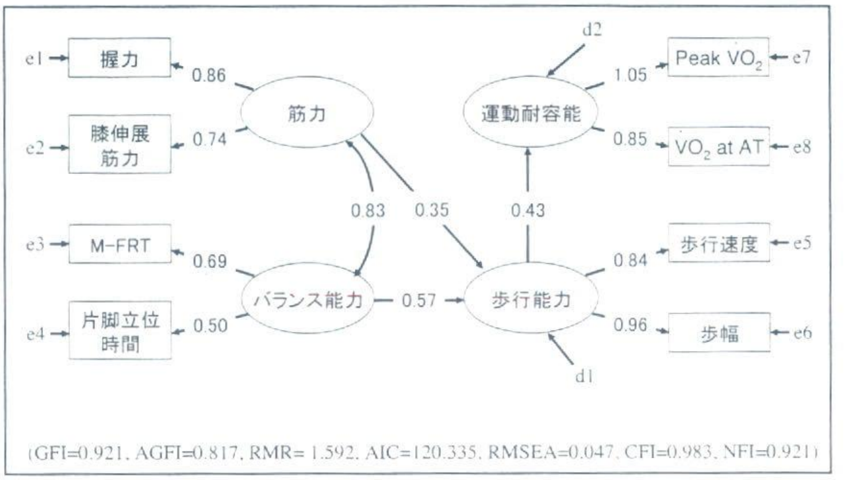

図1　高齢群における最高酸素摂取量と運動機能指標との関連性の検討

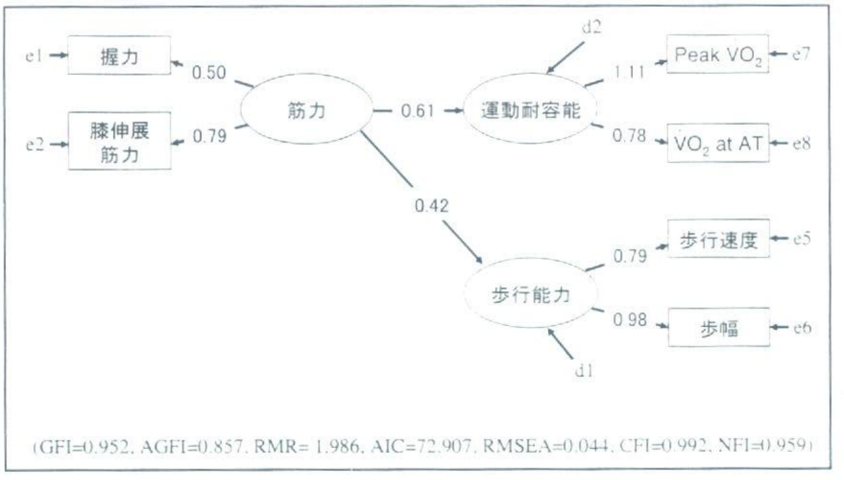

図2　壮年群における最高酸素摂取量と運動機能指標との関連性の検討

て，LVEFを除く各指標で有意に低値を示した．

表2に，高齢群と壮年群における各測定指標の間の相関係数を示した．高齢群においてPeak $\dot{V}O_2$と各運動機能指標との間には有意な相関関係が認められた．壮年群ではPeak $\dot{V}O_2$と握力，膝伸展筋力，歩行速度，歩幅との間に有意な相関関係が認められた．しかし，Peak $\dot{V}O_2$とM-FRT，片脚立位時間の間には有意な相関関係は認められなかった．

図1，2には，筋力，バランス能力，歩行能力が運動耐容能に影響するという因果モデルについての共分散構造分析結果を高齢群，壮年群別に示した．

高齢群のモデル適合度指標は，GFIは0.921，AGFIは0.817，RMRは1.592，RMSEAは0.047を示し，因果モデルは十分な適合であると判断された．歩行能力→運動耐容能間のパス係数は0.43，筋力→歩行能力間のパス係数は0.35，バランス能力→歩行能力間のパス係数は0.57を示し，統計的に有意な因果関係を示した（$p < 0.05$）．また，筋力，バランス能力，歩行能力，運動耐容能の潜在変数と，それぞれを構成する各観測変数との間には0.50～1.05と，いずれも統計的に有意なパス係数が示された（$p < 0.05$）．さらに，筋力とバランス能力の2変数は共変動であり，0.83の相関係数が示された（**図1**）．

壮年群では，GFIは0.952，AGFIは0.857，RMRは1.986，RMSEAは0.044を示し，高齢群の因果モデル同様に十分な適合であると判断された．筋力→運動耐容能間のパス係数は0.61，筋力→歩行能力間のパス係数は0.42を示し，統計的に有意な因果関係が示された（$p < 0.05$）．なお，壮年群におけるバランス能力は，どの潜在変数とも統計的に有意ではなく，因果モデルから削除された（**図2**）．

考　察

本研究では，因果モデルを総合的に検討するために，共分散構造分析を行った．その結果，運動耐容能に関わる運動機能指標は高齢群と壮年群で異なることが示された．壮年群においては，「筋力」の増減要因が「運動耐

容能」に直接的に関わるのに対し，高齢群の場合，「バランス能力」と「筋力」が，「歩行能力」を介して「運動耐容能」に間接的に影響することが明らかとなった．筋力低下やバランス能力の低下が要因で，歩行能力や運動耐容能が制限されることは先行研究で報告されており[8,11,16,17]，CRプログラム遅延例を防ぐためにも，早期から個々の症例に応じた個別プログラムの立案が必要とされている[18]．今回の研究結果は，これらの先行研究を裏づける結果となったが，新たな知見として，高齢群で運動耐容能向上には，歩行能力の向上が必要であり，その要因として筋力とバランス能力の改善が必要であることが示された．以上のことは，筋力やバランス能力の低下によって歩行能力や運動耐容能が制限される可能性を示唆しており，高齢群のCRプログラム施行に際しては，筋力，バランス能力の把握とともにその維持増強が重要であると考えられた．しかし，本研究では，運動機能以外の運動耐容能に関わる要因については言及できておらず，今後はそれらをふまえた検討が必要と考えられる．

本研究の限界

本研究で採用したCPXのプロトコールはトレッドミルを使用したものであり，全対象者がトレッドミルでの歩行が可能であった．また，歩行能力と運動耐容能の評価様式が同じ「歩行」であり，運動耐容能に対する分析バイアスが少なからず生じた可能性がある．

結　語

高齢群では，筋力やバランス能力の低下によって歩行能力や運動耐容能が制限される可能性があることから，高齢群のCRプログラム施行に際しては，筋力，バランス能力の把握とともにその維持増強が重要であると考えられた．

文　献

1) Wenger NK, Froelicher ES, Smith LK et al：Cardiac rehabilitation as seconddary prevention. Agency for Health Care Policy and Research and the National Heart, Lung and Blood Institute. Clin Pract Guidel Quick Ref Guide Clin：1-23, 1995
2) Mancini DM, Ferraro N, Nazzaro D et al：Respiratory muscle deoxygenation during exercise in patients with heart failure demonstrated with near-infrared spectroscopy. J Am Coll Cardiol 18：492-498, 1991
3) 井澤和大，森尾裕志，渡辺　敏 他：心不全症例に対する理学療法プログラム：入院期プログラムを中心として．理学療法 23：471-478, 2006
4) 平澤有里，長谷川輝美，山﨑裕司 他：健常者の等尺性膝伸展筋力．PTジャーナル 38：239-333, 2004
5) 金　俊東，久野譜也，相馬りか 他：加齢による下肢筋量の低下が歩行能力に及ぼす影響．体力科学 49：589-596, 2000
6) Ades PA, Savage PD, Brawner CA et al：Aerobic Capacity in patients entering cardiac rehabilitation. Circulation 113：2706-2712, 2006
7) Izawa K, Yamada S, Omori Y et al：The effect of stride walking on cardiovascular and electromyographic responses under different conditions in velocity or grade in healthy young women. J Jpn Phys Ther Assoc 3：27-32, 2000
8) Izawa K, Hirano Y, Omiya K et al：Improvement in physiologic measures and health-related quality of life following cardiac rehabilitation in patients with acute myocardial infarction. Circ J 68：315-320, 2004
9) 加藤宗則，山﨑裕司，柊　幸伸 他：ハンドヘルドダイナモメーターによる等尺性膝伸展筋力の測定：固定用ベルトの使用が検者間再現性に与える影響．総合リハ 29：1047-1050, 2001
10) 森尾裕志，大森圭貢，井澤和大 他：指示棒を用いたFunctional Reach Testの開発．総合リハ 35：487-493, 2007
11) 森尾裕志，井澤和大，渡辺　敏 他：高齢心大血管疾患患者における下肢筋力，前方リーチ距離と歩行自立度の関連について．心臓リハビリテーション 12：113-117, 2007
12) 笠原美千代，山﨑裕司，青木詩子 他：高齢患者における片脚立位時間と膝伸展筋力の関係．体力科学 50：369-373, 2001
13) 山﨑裕司，横山仁志，青木詩子 他：高齢患者の膝伸展筋力と歩行速度，歩行自立との関連．総合リハ 26：689-692, 1998
14) 田部井明美：SPSS完全活用法：共分散構造分析（Amos）によるアンケート処理．東京図書，pp 112-152, 2001
15) 小塩真司：SPSSとAmosによる心理・調査データ解析：因子分析・共分散構造分析まで．東京図書，pp160-210, 2004
16) 山﨑裕司，山田純生，渡辺　敏 他：心筋梗塞患者の下肢筋力：下肢筋力と運動耐容能の関連．総合リハ 22：41-44, 1994
17) 松永篤彦，神谷健太郎，増田　卓：入院期心臓リハビリテーションプログラム終了時の虚血性心疾患患者の下肢筋力と運動耐容能の関係．PTジャーナル 37：156-162, 2003
18) 高橋哲也，安達　仁，櫻井繁樹 他：心臓リハビリテーション遅延例への理学療法的アプローチ．心臓リハビリテーション6：62-65, 2001

J Rehabil Med 2008; 40: 225–230

ORIGINAL REPORT

GENDER-RELATED DIFFERENCES IN CLINICAL CHARACTERISTICS AND PHYSIOLOGICAL AND PSYCHOSOCIAL OUTCOMES OF JAPANESE PATIENTS AT ENTRY INTO PHASE II CARDIAC REHABILITATION

Kazuhiro P. Izawa, PT, PhD, MS[1], Koichiro Oka, PhD[2], Satoshi Watanabe, PT, BS[1], Hitoshi Yokoyama, PT, MS[1], Koji Hiraki, PT, BS[1],Yuji Morio, PT, MS[1], Yusuke Kasahara, PT, PhD, MS[1] and Kazuto Omiya, MD[3]

From the [1]Department of Rehabilitation Medicine, St Marianna University School of Medicine Hospital, Kanagawa, [2]Faculty of Sport Sciences, Waseda University, Saitama, [3]Division of Cardiology, Department of Internal Medicine, St. Marianna University School of Medicine, Kanagawa, Japan

Objective: **To examine gender differences in clinical characteristics and physiological and psychosocial outcomes at entry into phase II cardiac rehabilitation.**
Design: **Cross-sectional study.**
Subjects: **The study comprised 442 consecutive patients with cardiac diseases assessed at entry into a phase II cardiac rehabilitation programme.**
Methods: **Clinical characteristics of the patients, such as age, education, marital status, employment and body mass index, were obtained from hospital records. Oxygen uptake, handgrip and knee extensor muscle strength were measured to assess physiological outcomes. Self-efficacy for physical activity, hospital anxiety depression scale and health-related quality of life assessed by Short Form-36 were evaluated to assess psychosocial outcomes.**
Results: **The number of married women and their levels of education, employment and body mass index were significantly lower, and their ages higher, than those of the men. Measures of physiological outcome in women were significantly lower than those in men. Measures of self-efficacy for physical activity and Short Form-36 physical and emotional subscale scores were lower and anxiety levels higher in women than in men.**
Conclusion: **Cardiac rehabilitation programmes exclusively for women focusing on physiological outcomes, group counselling, and training to enhance physical and emotional domains may encourage increased participation by women in cardiac rehabilitation.**

Key words: gender difference, cardiac rehabilitation, clinical characteristics, physiological outcomes, psychosocial outcomes.

J Rehabil Med 2008; 40: 225–230

Correspondence address: Kazuhiro P. Izawa, Department of Rehabilitation Medicine, St Marianna University School of Medicine Hospital, 2-16-1 Sugao, Miyamae-ku, Kawasaki, Kanagawa 216-8511, Japan. E-mail: izawapk@ga2.so-net.ne.jp

Submitted June 11, 2007; accepted October 17, 2007

INTRODUCTION

Effective cardiac rehabilitation (CR) for patients with coronary heart disease (CHD) such as acute myocardial infarction (AMI) or following coronary artery bypass graft (CABG) surgery has been reported to improve exercise capacity, reduce coronary risk factors, improve health-related quality of life (HRQOL), and reduce cardiac events, hospitalization costs, sudden death and all-cause mortality (1–4). In recent years, researchers in several countries, after examining the benefits of CR separately for men and women, have called for added attention to the study of gender-related differences in CR outcomes (1–4).

The risk of developing CHD is known to be markedly different between men and women (5, 6). Several studies address gender-related differences in mortality and risk factors in Japan. Kawano et al. (5) suggested that hypertension, diabetes, current smoking, family history and hypercholesterolemia are associated with AMI in Japanese patients. In addition, there are gender-related differences in the order of importance of these risk factors for AMI. Moreover, Sasaki et al. (6) reported that in a 6-year observational study, the incidence of coronary events was 60% lower in women than in men. Although the correlation of serum total cholesterol and low-density lipoprotein cholesterol concentrations to coronary events was similar in men and women, the low-density lipoprotein cholesterol concentration associated with a decreased risk of coronary events was slightly higher in women. Diabetes mellitus was a stronger risk factor in women than in men and offset the women's advantage of lower risk for coronary events, especially in elderly patients.

However, the presence of CHD is a major predictor of physical disability, compounded by the effects of age and reduced physical activity. Women have significantly higher rates of disability than do men of the same age (7). Additionally, after a cardiac incident, women appear to be at greater risk of psychosocial impairment than do men (8–11). Studies comparing CR outcome between men and women report significantly poorer programme uptake for women (8–11). Thus, despite the benefits of phase II CR, limited data are available on outcomes of these treatments in women (8–11).

Although a few studies have investigated gender-related differences in coronary events and mortality in relation to risk factors, the relationship of gender difference in clinical characteristics and physiological and psychological outcomes in Japanese cardiac patients is unknown (11). We hypothesized

 ISSN 1650-1977
doi: 10.2340/16501977-0156

that at entry into phase II CR, women would have greater levels of physiological and psychological outcome impairment than would men. The purpose of the present study was to investigate whether gender-related differences exist between Japanese men and women in regard to clinical characteristics, physiological outcome measures of peak $\dot{V}O_2$, handgrip strength, and knee extensor muscle strength and measures of psychosocial outcome at entry into phase II CR.

METHODS

Study design and subjects

The present study was a cross-sectional study in which consecutive patients were selected from outpatients who completed an acute-phase CR programme at St Marianna University School of Medicine Hospital from November 1999 to August 2005. Inclusion criteria were a first AMI or CABG and successful completion of cardiopulmonary exercise testing (CPX) and handgrip and knee extensor muscle strength testing (3). Exclusion criteria were pre-existing extensive co-morbidity (e.g. cancer), New York Heart Association (NYHA) functional class IV, and neurological, peripheral vascular, orthopaedic or pulmonary disease. At the end of their acute-phase CR programme, physiological outcomes of 473 patients were assessed, and the patients were asked to complete psychosocial outcome testing.

Of the 473 patients, 442 were included in this study (371 men, mean age 60.6 years (standard deviation (SD) 10.3) and 71 women, mean age 63.6 years (SD 9.1)). Thirty-one patients were excluded due to inability to measure their peak $\dot{V}O_2$ or hand grip and knee muscle strength or because of inappropriate responses to the psychosocial outcome tests.

Ethics

The present study was approved by the St Marianna University School of Medicine Institutional Committee on Human Research (Approval No. 356). Written, informed consent was obtained from each patient.

Clinical characteristics of the patients

A cardiologist assessed left ventricular ejection fraction (LVEF) by ultrasonic echocardiography (UCG) as the index of cardiac function and objective indication of cardiac disease severity. We also evaluated patient age, sex, body mass index (BMI), education level, marital status and employment.

Physiological outcomes at entry into phase II CR

Peak $\dot{V}O_2$, handgrip strength and knee extensor muscle strength were measured to assess physiological outcomes of each patient at entry into a phase II CR programme. Subjects underwent CPX under a ramp treadmill protocol at entry into the programme (3). Peak $\dot{V}O_2$ was measured as the index of exercise capacity. Measurements made from expired gasses were used as indices of cardiovascular dynamics during exercise. Symptom-limited exercise testing was performed on a MAT-2500 treadmill (Fukuda Denshi Co., Tokyo, Japan). Throughout the test, a 12-lead ECG was monitored continuously, and heart rate was measured from the R-R interval of the ECG (ML-5000, Fukuda Denshi Co., Tokyo, Japan). Peak $\dot{V}O_2$ was measured during the exercise period with an AE-300S Aero monitor (Minato Ikagaku Co., Tokyo, Japan) and calculated with a personal computer (Epson Co., Nagano, Japan). The endpoint of exercise testing was determined according to the criteria of the American College of Sports Medicine (12).

Handgrip strength

A standard adjustable-handle JAMAR dynamometer (Bissell Healthcare Co., Grand Rapids, MI, USA) was used to measure handgrip strength as the index of upper-limb muscle strength and was set at the second grip position for all subjects (3). Attention was paid to a possible Valsalva effect, and measurements were made 3 times each on both hands. The highest value measured was used as the index of handgrip strength (kg).

Knee extensor muscle strength

The Biodex System 2 isokinetic dynamometer (Biodex Medical Systems, Inc., New York, USA) was used to measure knee extensor muscle strength as the index of lower-limb muscle strength. Testing was performed at a maximum of 5 repetitions for knee extensors at isokinetic speeds of 60°/sec. Isokinetic test results were analysed with the Biodex System 2 software (3). We measured the knee extensor muscle strength peak torque per body weight value (Nm/kg) of both knees and used the maximum value obtained as the index of knee extensor muscle strength.

Psychosocial outcomes

Self-efficacy for physical activity (SEPA), Hospital Anxiety Depression Scale (HADS) and HRQOL tests were used to assess psychosocial outcomes of each patient at entry into phase II CR.

Self-efficacy for physical activity. SEPA measures self-confidence for performance of a given activity or task and represents an individual's perceptions or beliefs about how capable he or she is of performing that specific activity or task (13–15). General SEPA was measured with the Japanese version of the SEPA because of its reliability and validity (15). The SEPA consists of 4 subscales: domains of walking, stair climbing, weight lifting and push off. It was measured at entry of the patients into a phase II CR programme. After testing of the 4 domains, the upper-body SEPA score (average scores of weight lifting + push off / 2) and lower-body SEPA score (average scores of walking + stair climbing / 2) were calculated. SEPA upper- and lower-body subscale scores range from 0 to 100. Lower scores indicate poorer, and higher scores better, levels of SEPA (15).

Hospital Anxiety Depression Scale. All patients enrolled in the present study completed the HADS to establish a baseline score. The HADS questionnaire, whose reliability has been fully validated (16, 17), is used extensively with hospital patients. It is quickly and easily completed and is well established among patients with cardiac diseases (17). One scale-score for anxiety and one for depression are computed from a 14-item checklist (7 items for anxiety and 7 items for depression). Patients with ≤ 7 points on the scale are not considered to be anxious or depressed, those with 8–10 points are suspected of being anxious or depressed, and those with ≥ 11 points are considered to be anxious or depressed (16, 17).

Health-related quality of life. General HRQOL was assessed with the Medical Outcome Study 36-item Short Form Health Survey (SF-36) (18–20). The SF-36 consists of 36 items representing 8 subscales that cover the domains of physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional and mental health. The SF-36 is a standardized, generic HRQOL measurement instrument that has been validated in the general normal Japanese population (18–20). It measures multidimensional properties of HRQOL on a 0–100 scale, with lower scores representing lower HRQOL and higher scores higher HRQOL (16–19).

Statistical analysis

Results are expressed as mean and SD. Unpaired t-test and χ^2 test were used to analyse differences in clinical profiles of the patients because comparisons between 2 groups (men and women) were performed for grip strength, knee extensor muscle strength and peak $\dot{V}O_2$. In addition, the unpaired t-test was used to test for differences between the 2 independent groups in average upper- and lower-body SEPA scores, HADS anxiety and depression scores and the 8 SF-36 subscales. Statistical analyses were performed with SPSS 12.0J statistical software (SPSS Japan, Inc., Tokyo, Japan). A p-value of < 0.05 was considered statistically significant.

RESULTS

Clinical characteristics of the patients

Clinical characteristics for all patients and differences between men and women are summarized in Table I. LVEF, AMI location, number of CABGs and medications were almost identical between the 2 groups. However, age, education, marital status, employment and BMI differed significantly between men and women.

Gender-related differences in physiological outcomes

No patient showed ischaemic ST changes or experienced chest pain or serious arrhythmia during CPX. Data collected from the 2 groups are presented in Table II. Comparisons were performed across the 2 groups after CPX and muscle strength testing. Peak $\dot{V}O_2$ scores in women were significantly lower than those in men ($t=6.5$, $p=0.01$). Scores for handgrip strength ($t=14.3$, $p=0.01$) and knee extensor muscle strength ($t=8.1$, $p=0.01$) in women were also significantly lower than those in men.

Gender-related differences in psychosocial outcomes

HADS. In regard to anxiety scores on the HADS, of the 371 men and 71 women in the present study, 254 (68.5%) men vs 37 (52.1%) women scored ≤7 points (no anxiety), 94 (25.3%) men vs 23 (32.4%) women scored 8–10 points (suspected anxiety) and 23 (6.2%) men vs 11 (15.5%) women scored ≥11 points (anxiety). In regard to HADS scores for depression, however, 210 (56.6%) men vs 43 (60.6%) women scored ≤7 points on the scale (no depression), 115 (31%) men vs 22 (30.9%) women scored 8–10 points (suspected depression) and 46 (12.4%) men vs 6 (8.5 %) women scored ≥11 points (depression). HADS anxiety scores in women were significantly higher than those in men ($t=2.1$, $p=0.03$). Although there was a tendency towards difference between the men and women in the HADS depression score, the difference was not significant ($t=1.7$, $p=0.07$). Differences in HADS scores between the 2 groups are shown in Table III.

Table I. *Clinical characteristics of the 442 patients*

	Men (n=371)	Women (n=71)	p-value
Age (years), mean (SD)	60.6 (10.3)	63.6 (9.1)	0.03*
BMI (kg/m²), mean (SD)	22.8 (4.1)	21.6 (3.7)	0.02*
Education (years), mean (SD)	13.1 (2.8)	12.0 (7.1)	0.04*
Married (%)	85	72	0.01*
Employed (%)	57	34	0.03*
LVEF (%), mean (SD)	50.7 (8.2)	52.2 (8.8)	0.07
AMI location (n)			
Inferior	153	26	0.43
Anterior	123	23	
Lateral	21	5	
CABG (n)	74	17	
Medications (n)			
Nitrates	226	45	0.14
Calcium antagonists	79	14	
β-blockers	117	24	
ACEI or ARB	211	37	

*Significant difference between men and women. SD: standard deviation; BMI: body mass index; LVEF: left ventricular ejection fraction; AMI: acute myocardial infarction; CABG: coronary artery bypass graft; ACEI: angiotensin converting enzyme inhibitor; ARB: angiotensin receptor blocker.

Table II. *Comparison of physiological outcomes by gender in patients with cardiac diseases. Data are expressed as mean and standard deviation.*

Variable	Men (n=371)	Women (n=71)	t-value	p-value
Peak $\dot{V}O_2$ (ml/kg/min)	24.3 (5.0)	19.9 (3.6)	6.5	0.01*
Handgrip strength (kg)	38.1 (7.9)	22.9 (4.1)	14.3	0.01*
Knee extensor muscle strength (Nm/kg)	1.8 (0.4)	1.4 (0.4)	8.1	0.01*

*Significant difference between men and women.

SEPA. Gender-related differences in upper- and lower-body SEPA scores between the 2 groups are also presented in Table III. Upper-body ($t=6.9$, $p=0.01$) and lower-body ($t=11.1$, $p=0.01$) scores in women were significantly lower than those in men.

HRQOL. Gender-related differences in the 8 SF-36 HRQOL subscales are presented in Table IV. SF-36 scores for physical functioning ($t=4.7$, $p = 0.01$), role-physical ($t=3.3$, $p=0.01$), vitality ($t=2.0$, $p=0.01$) and role-emotional ($t=3.2$, $p=0.01$) subscales were significantly lower in women than in men. No significant difference was detected between groups in the bodily pain ($t=1.4$, $p=0.14$), general health ($t=0.9$, $p=0.34$), social functioning ($t=0.1$, $p=0.84$) or mental health ($t=0.3$, $p=0.75$) subscales scores.

DISCUSSION

The main purpose of the present study was to assess gender-related differences between men and women at entry into a phase II CR programme in relation to clinical characteristics and physiological and psychosocial outcomes.

Gender-related differences in patient clinical characteristics

There were no statistically significant gender-related differences in LVEF, AMI location, CABG or medications. However, the women were significantly older, fewer were married, and their levels of education, employment and BMI were lower than

Table III. *Comparison of psychosocial outcomes (HADS and SEPA scores) by gender. Data are expressed as mean and standard deviation.*

	Men (n=371)	Women (n=71)	t-value	p-value
HADS subscales				
Anxiety	5.3 (3.3)	6.3 (3.6)	2.1	0.03*
Depression	6.8 (3.2)	5.9 (3.1)	1.7	0.07
SEPA				
Upper-body activity	70.3 (21.7)	49.2 (22.3)	6.9	0.01*
Lower-body activity	65.9 (23.4)	30.2 (21.4)	11.1	0.01*

*Significant difference between men and women.
HADS: hospital anxiety depression scale; SEPA: self-efficacy for physical activity.

Table IV. *Comparison of psychosocial outcomes (SF-36 subscale scores) by gender. Data are expressed as mean and standard deviation.*

SF-36 subscales	Men (n=371)	Women (n=71)	t-value	p-value
Physical functioning	83.8 (12.7)	75.0 (15.2)	4.7	0.01*
Role-physical	43.1 (42.4)	36.1 (23.3)	3.3	0.01*
Bodily pain	63.5 (30.7)	57.4 (26.5)	1.4	0.14
General health	54.7 (18.6)	52.3 (14.4)	0.9	0.34
Vitality	59.5 (21.4)	53.3 (19.8)	2.0	0.01*
Social functioning	65.5 (32.4)	64.7 (27.0)	0.1	0.84
Role-emotional	49.0 (36.5)	40.1 (28.4)	3.2	0.01*
Mental health	66.4 (20.9)	65.5 (20.5)	0.3	0.75

*Significant difference between men and women.
SF-36: Short Form-36

those of the men. A previous report (10) suggested that women tend to be older when they begin phase II CR, and a greater number are divorced and/or widowed or have an older spouse who also might require physiological and/or psychosocial care. Moreover, women entering CR are less conditioned than men, which may affect their ability for self-care, performance of routine activities of daily living and other enjoyment (e.g. meeting friends and recreation) (10). In the present study, a significant difference was noted in the number of married men (85%) vs married women (72%). Of the unmarried subjects, 15% of the men and 38% of the women were divorced or widowed. With regard to gender-related differences in survival after AMI, Fiebach et al. (9) reported that a significantly greater number of the women in their study were widowed. Although we did not ascertain what percentage of women were widowed vs divorced in the present study, the average age of the women tended to be higher than that of the men. So, one reason for the number of married women being lower than that of the men might be that the percentage of widowed women was higher.

In the present study, fewer of the women were employed, and they had a lower level of education than the men. These findings support those of previous studies. Stern et al. (21) reported that compared with working men, women working before an AMI or CABG did not return to work as frequently as did men after these events. Boogaard (22) also reported that 67% of women failed to return to work at 6 months after AMI compared with only 10% of men. Education level may not change directly in relation to CR programmes, but employment may change over time as a result of CR.

The BMI of the women in the present study was significantly lower than that of the men. In general, BMI needs to be reduced for secondary prevention after CR and exercise training. Obesity is more common in women with CAD, and previous data have shown that obesity is strongly and independently related to CAD events in women. However, Davos et al. (23) suggested that in patients with chronic heart failure without cachexia, increasing BMI is not an adverse prognostic element and that thinner patients appear to have a poor prognosis. Moreover, Landi et al. (24) suggested that low BMI (<22 kg/m^2) remains a significant and independent predictor of shortened survival in older people living in the community. Thus, BMI in older women with cardiac disease may need to be maintained at >22 kg/m^2.

Gender-related differences in physiological outcomes

In the present study, peak $\dot{V}O_2$ in women was significantly lower than that in men. Previously, a few studies examining baseline gender-related differences in exercise measures have reported that women consistently tend to have lower exercise capacities than men. Recently, Ades et al. (1) reported that peak $\dot{V}O_2$, which was measured in 2896 patients entering CR, was higher in men than women. They suggested that the extremely low peak $\dot{V}O_2$ values of the patients, particularly those of women, on entry into CR underscores the importance of CR after a major cardiac event to improve physical function and long-term prognosis. The present study strongly supports their finding of significantly lower exercise capacity in women than in men.Cannistra et al. (25) also suggested statistical similarities in the improvement noted in men and women in exercise capacity. This improvement in functional capacity for women has been documented previously in other studies of CR (11). Because women begin CR programmes with lower functional capacity (1), the clinical benefit may in fact be greater for women than for men, who already have a good exercise capacity.

In the present study, both grip strength and knee extensor muscle strength were significantly different for men than for women. Grip strength is a predictor of mortality and morbidity in the general population (26). In addition, lower grip and knee extensor muscle strengths are associated with incidence as well as prevalence of disability, suggesting that age-related loss of muscle mass and volitional muscle strength can be a cause as well as a consequence of physical disability (27).

Falls occur frequently in the older population and are often a source of disability in women (28). In a study to determine risk factors for falling in older men and women living in nursing homes and to compare characteristics of fallers vs non-fallers, Sieri & Beretta (29) found that men who had fallen had greater deficits of ankle plantar-flexion strength and power, whereas women who had fallen had greater deficit of knee extensor muscle strength and lower walking speed. These results show that lack of muscle power affects ability in women and that interventions for improving contractile velocity should be pursued. Therefore, it is necessary to enforce more positive training by concentrating on improving both upper- and lower-extremity muscle strength in women.

Gender-related differences in psychosocial outcomes

Although the HADS anxiety and depression scores in the present study indicated neither depression nor anxiety (average scores for anxiety and depression were <8 points in both groups), the women had higher levels of anxiety than did the men. Brezinka et al. (30) suggested that women have higher levels of anxiety and exhaustion at entry into phase II CR programmes, and this, in combination with their significantly lower perceived exercise capacity, might prevent them from participating in physical exercise training. These findings may be supported by the present study in that the women had a higher anxiety level in relation to a lower level of physiological outcome in comparison with the men entering CR. However, although there was a tendency towards difference between the men and women in the HADS depression score, the difference was not significant (Table III).

Josephson et al. (31) reported that depression scores assessed by the Beck Depression Inventory (BDI) were higher for women than men in a sample of patients with cardiac diseases tested after cardiac surgery such as CABGs. This discrepancy with the results of the present study may be related to differences in patient characteristics and the tool used for evaluation of depression. One possible reason may be that a lower percentage of patients in their study were post-AMI patients. Although our study patients included those with AMI (but not those with angina), only 40% of men and 56% of the women in their study had suffered an AMI. In addition, we used the HADS to assess depression, and they used the BDI. The differences in type of cardiac disease and/or evaluation tool may play a part in attenuating the magnitude of the gender difference in the HADS depression score in the present study.

Engebretson et al. (2) reported that in a 12-week phase II CR programme, affective distress (of both low and high anxiety) decreased, as measured by the Profile of Mood States-Short Form test. Particularly, a phase II CR programme was more effective when participants entered with a baseline of high rather than low anxiety. Another study also suggested that neither depression nor anxiety indices were reduced in women after a CR programme (32). We did not investigate the effects of CR on anxiety and depression with respect to gender difference; therefore, future evaluation of these effects in women is necessary.

Upper- and lower-body SEPA scores in women were also lower than those in men in the present study. Previous studies (4, 10) suggest a cross-sectional correlation of self-efficacy with exercise adherence, physiological outcomes and HRQOL. In the present study, the values of grip strength, knee extensor muscle strength and peak $\dot{V}O_2$ in women are lower than those of men. Thus, SEPA may also be related to physiological outcomes on entry into CR. Moreover, McAuley et al. (33) reported that positive feedback about exercise performance may increase positive affect and reduce negative feelings associated with exercise in women. Thus, to improve SEPA, positive feedback about exercise is necessary to improve HRQOL in women.

With regard to HRQOL, the SF-36 physical functioning and vitality subscale scores in the women were lower than those of the men in the present study. Women's physiological outcomes in relation to SEPA (3, 4, 11) and HRQOL (11) were lower than those of the men. Therefore, the combination of the women's significantly lower physiological outcome measures and lower SEPA scores may be related to their lower physical functioning and vitality scores. In addition, the women's role-physical and role-emotional subscale scores were also significantly lower than those of the men (Table IV).

In comparison with the men in the present study, fewer women were employed or married, and their anxiety level was greater. Men who have been employed in a company or other work outside the home may be likely to view retirement as a reward for many years of hard work or as relief from major responsibility. However, individuals forced into retirement because of failing health often show poor psychosocial adjustment (34). Retired women are expected to continue assuming most domestic tasks (34). Therefore, housewives may be more likely to experience a sense of inadequacy or failure when they are unable to perform everyday tasks associated with home management. These gender differences might be related to the role-physical and emotional scores recorded among the female respondents.

We did not investigate social support and leisure-time physical activity during the day and thus could not correlate these factors with the role-physical and emotional subscale scores of the SF-36. Therefore, a further study is needed to evaluate the relationship between these factors.

In general, after CR, behavioural characteristics and nearly all components of QOL improve to a similar degree in men and women (35). We previously reported that exercise-based CR for AMI and CABG improved not only physiological outcomes but also SEPA and HRQOL (3, 4). Particularly in regard to HRQOL, exercise-based CR improved the physical component and vitality subscales of the SF-36 (3, 4). In the present study, we found that at baseline, women not only had significantly lower exercise capacity and muscle strength but also lower SEPA and higher HADS scores and lower HRQOL than did the men. Therefore, improvement in physiological and psychosocial outcomes may offer greater clinical benefit to women than to men. However, exercise-based CR alone may not change mental health. In female patients particularly, we should consider improvements in exercise training in addition to stress management, coping measures and group counselling.

There are several limitations in the present study. One limitation is the cross-sectional design of the study. It would be highly desirable to document longitudinal change in physiological and psychosocial outcomes in cardiac patients, and evaluation of gender-related differences with regard to the effect of CR and mental status on physiological and psychosocial outcomes over the long-term after CR is necessary. Another limitation is that clinical diagnosis of anxiety and depressive disorders cannot be made with the HADS. However, the HADS has been shown to be a reliable and valid screening instrument for symptoms of anxiety and depression in general internal medicine patients (32). Despite these limitations, we believe that the findings of the present study are important because the sample size was large enough to yield significant results from the test instrument scores.

In conclusion, the present study is an initial step in identifying gender-related differences associated with physiological and psychological outcomes in Japanese patients with cardiac diseases. We found baseline gender-related differences in the areas of physiological outcome and psychosocial functioning that suggest women may have lower SEPA and HRQOL and higher anxiety than men on entry into a phase II CR programme. In particular, the present study indicates that women have reduced physiological and psychosocial outcomes and that both should be addressed in Japanese patients with cardiac diseases at entry into phase II CR programmes. Eventually, CR programmes exclusively for women that focus not only on physiological outcomes but also on group counselling and training to enhance the role-physical and emotional domains might encourage more women to participate. Additional study is needed to evaluate whether these challenges influence long-term outcomes and affect gender-related differences in CR over longer periods in these patients.

ACKNOWLEDGEMENT

This study was supported in part by a Grants-in-Aid for Scientific Research (No. 16200042) from the Japan Society for the Promotion of Science.

REFERENCES

1. Ades PA, Savage PD, Brawner CA, Lyon CE, Ehrman JK, Bunn JY, et al. Aerobic capacity in patients entering cardiac rehabilitation. Circulation 2006; 113: 2706–2712.
2. Engebretson TO, Clark MM, Niaura RS, Phillips T, Albrecht A, Tilkemeier P. Quality of life and anxiety in a phase II cardiac rehabilitation program. Med Sci Sports Exerc 1999; 31: 216–223.
3. Izawa K, Hirano Y, Yamada S, Oka K, Omiya K, Iijima S. Improvement in physiological outcomes and health-related quality of life following cardiac rehabilitation in patients with acute myocardial infarction. Circ J 2004; 68: 315–320.
4. Izawa KP, Oka K, Watanabe S. Research on exercise adherence: a review of primary studies. Crit Rev Phys Rehabil Med 2006; 18: 95–106.
5. Kawano H, Soejima H, Kojima S, Kitagawa A, Ogawa H; Japanese Acute Coronary Syndrome Study (JACSS) Investigators. Sex differences of risk factors for acute myocardial infarction in Japanese patients. Circ J 2006; 70: 513–517.
6. Sasaki J, Kita T, Mabuchi H, Matsuzaki M, Matsuzawa Y, Nakaya N, et al. Gender difference in coronary events in relation to risk factors in Japanese hypercholesterolemic patients treated with low-dose simvastatin. Circ J 2006; 70: 810–814.
7. Ades PA, Savage PD, Cress ME, Brochu M, Lee NM, Poehlman ET. Resistance training on physical performance in disabled older female cardiac patients. Med Sci Sports Exerc 2003; 35: 1265–1270.
8. Todaro JF, Shen BJ, Niaura R, Tilkemeier PL, Roberts BH. Do men and women achieve similar benefits from cardiac rehabilitation? J Cardiopulm Rehabil 2004; 24: 45–51.
9. Fiebach NH, Viscoli CM, Horwitz RI. Differences between women and men in survival after myocardial infarction. Biology or methodology? JAMA 1990; 263: 1092–1096.
10. Gardner JK, McConnell TR, Klinger TA, Herman CP, Hauck CA, Laubach Jr CA. Quality of life and self-efficacy: gender and diagnoses considerations for management during cardiac rehabilitation. J Cardiopulm Rehabil 2003; 23: 299–306.
11. Oka K, Izawa K. Gender differences in cardiac rehabilitation. In: Yamada S, editor. Rigakuryoho MOOK 12. Tokyo: Miwa Shoten; 2005: p. 196–201 (in Japanese).
12. Hanson P. Clinical exercise testing. In: Blair SN, Painter P, Pate RR, Smith LK, Taylor CB, editors. Resource manual for guidelines for exercise testing and prescription. Philadelphia: Lea & Febiger; 1988: p. 205–222.
13. Bandura A. Self-efficacy mechanism in human agency. Am Psychol 1982; 37: 122–147.
14. Oldridge NB, Rogowski BL. Self-efficacy and in-patient cardiac rehabilitation. Am J Cardiol 1990; 66: 362–365.
15. Oka K. Exercise adherence-promote of physical activity and exercise. In: Sakano Y, Maeda M, editors. Clinical psychology of self-efficacy. Kyoto: Kitaouji Syobo; 2002, p. 218–234 (in Japanese).
16. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand 1983; 67: 361–370.
17. Herrmann C. International experiences with the Hospital Anxiety and Depression Scale – a review of validation data and clinical results. J Psychosom Res 1997; 42: 17–41.
18. Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992; 30: 473–483.
19. Fukuhara S, Ware JE Jr., Kosinski M, Wada S, Gandek B. Psychometric and clinical tests of validity of the Japanese SF-36 Health Survey. J Clin Epidemiol 1998; 51: 1045–1053.
20. Fukuhara S, Suzukamo Y, Bito S, Kurokawa K, editors. Manual of SF-36 Japanese Version 1.2. Tokyo: Public Health Research Foundation; 2001.
21. Stern MJ, Pascale L, Ackerman A. Life adjustment postmyocardial infarction: determining predictive variables. Arch Intern Med 1977; 137: 1680–1685.
22. Boogaard MA. Rehabilitation of the female patient after myocardial infarction. Nurs Clin North Am 1984; 19: 433–440.
23. Davos CH, Doehner W, Rauchhaus M, Cicoira M, Francis DP, Coats AJ, et al. Body mass and survival in patients with chronic heart failure without cachexia: the importance of obesity. J Card Fail 2003; 9: 29–35.
24. Landi F, Zuccala G, Gambassi G, Incalzi RA, Manigrasso L, Pagano F, et al. Body mass index and mortality among older people living in the community. J Am Geriatr Soc 1999; 47: 1072–1076.
25. Cannistra LB, Balady GJ, O'Malley CJ, Weiner DA, Ryan TJ. Comparison of the clinical profile and outcome of women and men in cardiac rehabilitation. Am J Cardiol 1992; 69: 1274–1279.
26. Syddall H, Cooper C, Martin F, Briggs R, Aihie Sayer A. Is grip strength a useful single marker of frailty? Age Aging 2003; 32: 650–656.
27. Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, et al. Midlife hand grip strength as a predictor of old age disability. JAMA 1999; 281: 558–560.
28. Yamasaki H, Ohmori Y, Hasegawa T. Relationship between isometric knee extensor strength and mobility in the elderly patients-the effect of sexual specificity. Kochi Rehabilitation Institute 2005; 7: 47–53 (in Japanese).
29. Sieri T, Beretta G. Fall risk assessment in very old males and females living in nursing homes. Disabil Rehabil 2004; 26: 718–723.
30. Brezinka V, Dusseldorp E, Maes S. Gender differences in psychosocial profile at entry into cardiac rehabilitation. J Cardiopulm Rehabil 1998; 18: 445–449.
31. Josephson EA, Casey EC, Waechter D, Rosneck J, Hughes JW. Gender and depression symptoms in cardiac rehabilitation: women initially exhibit higher depression scores but experience more improvement. J Cardiopulm Rehabil 2006; 26: 164–166.
32. Lavie CJ, Milani RV. Effects of cardiac rehabilitation programs on exercise capacity, coronary risk factors, behavioral characteristics, and quality of life in a large elderly cohort. Am J Cardiol 1995; 76: 177–179.
33. McAuley, E Talbot H, Martinez S. Manipulating self-efficacy in the exercise environment in women: influence on affective responses. Health Psychol 1999; 18: 288–294.
34. Loose MS, Fernhall B. Differences in quality of life among male and female cardiac rehabilitation participants. J Cardiopulm Rehabil 1995; 15: 225–231.
35. Herrmann C. Screening for major depression in a group of diabetic patients. Psychosom Med 1997; 59: 559–560.

International Journal of Cardiology 129 (2008) 180–186

International Journal of Cardiology

www.elsevier.com/locate/ijcard

The exercise training effects of skeletal muscle strength and muscle volume to improve functional capacity in patients with myocardial infarction

Keisuke Kida *, Naohiko Osada, Yoshihiro J. Akashi, Hiromitsu Sekizuka, Kazuto Omiya, Fumihiko Miyake

Division of Cardiology, Department of Internal Medicine, St. Marianna University School of Medicine, Kawasaki, Japan

Received 3 August 2007; received in revised form 12 April 2008; accepted 23 April 2008
Available online 16 July 2008

Abstract

Background: No previous studies have fully investigated the exercise training effect on the skeletal muscle strength and volume to improve the exercise capacity in patients with myocardial infarction (MI). The present study was performed based on a hypothesis that the relationship between exercise capacity, skeletal muscle strength and volume might be changed by the amount of skeletal muscle volume in MI patients up to 3 months after the onset.

Methods: Seventy patients with MI underwent symptom-limited cardiopulmonary exercise testing using a treadmill. The lower limb muscle volume (MV) was evaluated according to electrical impedance analysis and the maximal knee extension strength (Peak torque, PT) was measured by a Biodex. All patients participated in 12-week exercise training program. The subjects were divided into 2 groups on the basis of MV: Group H, MV ≧ 22 kg; Group L, MV < 22 kg. Delta values were calculated as follows: the value at 3 months minus the value at 1 month.

Results: A positive and significant correlation was observed between the delta PT and delta peak VO_2 ($r = 0.50$, $p = 0.005$) only in the L group. No significant correlation was observed between the delta peak VO_2 and the delta lower limb MV or between the delta lower limb MV and the delta PT in the 2 groups.

Conclusions: Cardiac rehabilitation program combined with resistance and aerobic training improved exercise capacity and increased not the skeletal muscle volume but the skeletal muscle strength in patients with MI in their recovery phase. It was presumed that the improvement of exercise capacity was determined by the skeletal muscle strength not by the muscle volume especially in MI patients with low muscle volume.

Keywords: Exercise training; Functional capacity; Skeletal muscle; Myocardial infarction; Bioelectrical impedance analysis; Cardiac rehabilitation

1. Introduction

Cardiac rehabilitation (CR) program has been shown to reduce mortality and morbidity [1,2] and improve exercise capacity in patients with acute myocardial infarction (AMI). Especially, the lower limb muscle function is an important peripheral factor in cardiac function [3–8]. Our previous study has concluded that exercise capacity in patients with myocardial infarction (MI) was determined by the strength and volume of the skeletal muscle [3].

Some studies have reported that the combination of aerobic and weight training was effective to increase skeletal muscle volume [5,7,8]. In our previous study, the relationship between the skeletal muscle volume, strength and exercise

* Corresponding author. Division of Cardiology, Department of Internal Medicine, St. Marianna University School of Medicine, 2-16-1 Sugao Miyamae-ku, Kawasaki-city, Kanagawa, 216-8511, Japan. Tel.: +81 44 977 8111; fax: +81 44 976 7093.

E-mail address: heart-kida@marianna-u.ac.jp (K. Kida).

0167-5273/$ - see front matter © 2008 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.ijcard.2008.04.031

capacity was investigated in patients with MI who performed CR program in the acute phase [3]. Unfortunately, our previous study result was insufficient to evaluate the change of skeletal muscle volume and strength by exercise training and the influence of CR program.

Therefore, the present study was performed based on a hypothesis that the relationship between exercise capacity, skeletal muscle strength, and skeletal muscle volume might be changed by the amount of skeletal muscle volume in MI patients up to 3 months after the onset.

2. Methods

2.1. Subjects

This study was conducted on 70 male patients (a mean age of 60.3 ± 10.3 years) between May 2003 and July 2005 at St. Marianna University School of Medicine Hospital in Kawasaki, Japan. Thirty-eight of the patients had anterior MI, 22 had inferior MI, and 10 had lateral MI. Patients with post-infarction angina, critical arrhythmia, unstable heart failures, chronic lung disease, hereditary or acquired neuromuscular disorders were excluded. Percutaneous coronary intervention (PCI), coronary thrombolysis, and conservative medical treatment during the acute phase of MI were performed in 57, 4 and 9 subjects, respectively. Forty of the patients had one-vessel disease, 26 patients had two-vessel disease, and 4 patients had three-vessel disease before PCI. All patients performed cardiopulmonary exercise testing (CPX) 1 month after the AMI onset and took part in the acute phase CR program for 4 weeks during their hospitalization. After the acute phase CR program ended, we recommended the patients to participate in an 8-week recovery phase CR program. All patients remained clinically stable after the onset of MI, and none were hospitalized or had any medication changes after discharge. We measured the lower limb muscle strength and the muscle volume at 1 and 3 months after 12-week CR program and analyzed increased exercise capacity. We also calculated delta values as follow; the value at 3 months minus the value at 1 month.

2.2. Cardiopulmonary exercise testing

Symptom-limited CPX was performed at 1 and 3 months after the onset of MI using a MAT-2500 treadmill (Fukuda Denshi Co., Tokyo, Japan). After an initial 3-minute rest on the treadmill and 3-minute warm-up (speed 1.6 km/h; grade 0%), the patients underwent the CPX at a gradually increasing intensity (load increased at 1-minute intervals). The 12-lead ECG was monitored continuously and heart rate (HR) was measured with R-R interval of ECG (ML-5000, Fukuda Denshi Co., Tokyo, Japan). The systolic blood pressure was measured with a cuff via an automatic blood pressure monitor (Stress Test System, STBP-780, Colin, Aichi, Japan) at 1-minute interval. Expired gas analysis was performed throughout the test on the breath-by-breath basis with an AE-280 cart (Minato Medical Science, Osaka, Japan). The anaerobic threshold (AT) and the peak oxygen uptake (peak VO_2) were calculated based on the CPX results. AT was determined by the original V-slope method [9]. The criteria to halt the exercise test were determined according to the guidelines of the American College of Sports Medicine [10]. An apparent leveling off of VO_2 (a VO_2 plateau in spite of increasing exercise intensity) was used as a sign to terminate the exercise.

2.3. Measurement of skeletal muscle volume

Before starting CPX, a single-cycle bioelectrical impedance data acquisition system (Muscle-α, Art Haven 9 Co., Kyoto, Japan) was used to measure the muscle volume that was highly correlated to the one determined by magnetic resonance imaging (MRI) [11]. Each patient was asked to rest quietly on a bed in the supine position. The 4 limbs were fully extended straight outward from the trunk at 30° angle to ensure that none touched any of the others. After attaching the electrodes to the most distal fingers and toes of each extremity, a voltage determination electrode was also attached to each extremity as an impedance determination locus. Electrodes were attached to 12 measurement sites in total: the root of the middle finger on the dorsum of each hand, the dorsal side of each wrist, the root of the middle toe on the dorsum of each foot, the center of the dorsal side of each ankle, and the lateral side of each elbow and knee. The patients were divided into the 2 groups according to mean skeletal muscle volume (group L; muscle volume < 22 kg, group H; muscle volume ≥ 22 kg).

2.4. Measurement of skeletal muscle strength

A Biodex System 2 isokinetic dynamometer (Biodex Medical Systems, Inc., New York, NY, USA) was used to measure knee extension muscular strength (peak torque: PT) as an index of the muscular strength of the lower limb. The machine was calibrated at initiation of the study. Patients underwent the test in a seated position with hip flexion at 80° and stabilization straps applied to the trunk, waist, and thighs. The resistance pad was placed 10 cm proximal to the medical malleoulus. The range of motion during the test was set between 0° and 90° for knee flexion. All patients performed 3-time sub maximal and 1-time maximal warm-up at the test speed prior to the test [12]. We performed the isokinetic testing in the concentric contraction mode with verbal command for the consistency of the patients' performances. The test was repeated 5 times at most, at isokinetic speed of 60° per second. These isokinetic test results were analyzed using Biodex System 2 software [13].

2.5. Exercise training

CR program in the recovery phrase was determined based on the CPX results, muscle strength testing and perceived exertion ascertained at the end of inpatient CR program in

Table 1
Patients characteristics at 1st and 3rd month

	1st month		3rd month	
	L group	H group	L group	H group
Number	37	33	37	33
Male/female	37/0	33/0	37/0	33/0
Age (years)	59.7±9.8	61.0±10.9	59.7±9.8	61.0±10.9
Height (cm)	164.8±6.7	168.0±7.5	165.4±7.4	167.9±7.5
Weight (kg)	60.0±6.4	70.8±6.9	60.3±6.2	70.9±7.3
BMI (kg/m^2)	22.0±2.2	25.2±2.7	22.1±2.3	25.2±2.7
NYHA classification				
I	9	8	10	8
II	17	15	17	16
III	11	10	10	9
IV	0	0	0	0
Medications				
ACE-I	14 (38%)	13(39%)	14(38%)	13(39%)
A-II	20(54%)	16(48%)	20(54%)	16(.48%)
Beta-blockade	8(22%)	4(12%)	8(22%)	4(12%)
Diuretics	5(14%)	5(15%)	5(14%)	5(15%)
Nitrate	29(78%)	28(85%)	29(78%)	28(85%)
Digoxine	0(0%)	0(0%)	0(0%)	0(0%)
Calcium blockade	8(22%)	5(15%)	8(22%)	5(15%)

NYHA = New York Association; EF = ejection fraction
ACE-I angiotensin converting enzyme inhibition; A-II = angiotensin-II antagonist.
Values were expressed as mean±S.D.

the acute phase. Patients discharged from hospital participated in 1-hour supervised program combined with aerobic and resistance training twice in a week. Exercise training was consisted of warm-up, aerobic exercise, stretch, resistance training, and cool down. The intensity of aerobic exercise on a treadmill was maintained at AT heart rate level. Patients performed 4 sets of 2-kind upper-extremity exercise trainings (5 times of shoulder flexion and abduction in the anatomical position) with iron weight arrays. Perceived exertion rating after training was 11 to 13 on the Borg 6–20 scale. Then, patients took 4 sets of lower extremity exercise training (5 times of knee extension and calf raise) with weights applied to ankles at 50% of the maximum resistance. The intensity of calf raise exercise was kept at 11 to 13 ratings of perceived exertion. Patients were allowed to take prescribed cardiac medications on the exercise test day, and they took exercise training for 3 months.

2.6. Statistical analysis

All values were indicated as means±standard deviation. Student's *t*-test was used to compare the mean values of parameters between the 2 groups. Spearman's regression analysis was used to analyze the correlations of 2 parameters. The level of statistical significance for measurements was set at less than 5%.

2.7. Ethics

The present study was approved by St. Marianna University School of Medicine Institutional Committee on Human Research. Informed consent was obtained from all of the patients prior to their enrollment.

3. Results

The patient backgrounds are shown in Table 1. No patients suffered from major complications such as exacerbation of heart failure, sudden cardiac death, or any other cardiac events during the study period. No significant differences in age, left ventricular ejection fraction, New York Heart Association Classification, peak VO_2, and AT were observed between the L and H groups.

3.1. Exercise capacity

The end-point of the exercise test was determined by leg fatigue and shortness of breath. No patients showed ischemic ST changes or experienced chest pain or serious arrhythmia during the exercise test. Table 2 shows the oxygen uptake response and respiratory exchange ratio (RER) in the L and H groups. Significant increases of peak VO_2 as well as AT were observed in the 2 groups: the L group, 1607±380 to 1753±457 ml/min ($p<0.0001$) and 1114±254 to 1254±307 ml/min ($p<0.0001$); and the H group, 1962±420 to 2098±491 ml/min ($p<0.001$) and 1365±272 to 1458±306 ml/min ($p<0.01$), respectively. Meanwhile, no significant change of RER was observed in the 2 groups.

3.2. Skeletal muscle volume and skeletal muscle strength

Table 2 shows the skeletal muscle volume of the whole body, upper limbs, lower limbs and the skeletal muscle

Table 2
The data of exercise capacity, muscle volume and strength

	L group		H group	
	1 month	3 month	1 month	3 month
Exercise capacity				
AT (ml/min)	1114±254	1254±307*	1365±272	1458±306¶
Peak VO_2(ml/min)	1607±380	1753±457*	1692±420	2098±491‡
VE/VCO_2 slope (ml/ml)	29.0±5.5	28.7±4.9	29.3±3.7	28.1±4.2
Peak RER	1.17±0.09	1.16±0.11	1.16±0.07	1.16±0.07
Muscle volume (kg)				
Whole body	19.6±1.6	19.9±2.0	24.5±2.0	24.5±2.2
Inferior limb	4.50±0.39	4.59±0.44	5.45±0.46	5.47±0.52
Thigh	2.69±0.28	2.76±0.36	3.29±0.30	3.30±0.39
Crus	1.81±0.23	1.83±0.20	2.16±0.24	2.17±0.24
Peak torque/body weight (N/m)				
Right	108.1±33.3	120.6±36.4*	133.1±34.0	140.2±39.1#
Left	107.8±34.8	117.3±35.8‡	127.9±35.2	139.6±41.8¶
Peak	113.4±34.5	126.0±37.5*	137.9±33.3	146.1±39.7#

AT = anaerobatic threshold; Peak VO_2 = peak oxygen uptake; RER = respiratory exchange ratio. Values were expressed as mean±S.D.
*$p<0.0001$ vs 1 month; ¶$p<0.01$ vs 1 month; ‡$p<0.001$ vs 1 month; # $p<0.05$ vs 1 month.