LÉKAŘSKÁ FAKULTA MASARYKOVY UNIVERZITY

V BRNĚ

AEROBNÍ TRÉNINK NEMOCNÝCH S CHRONICKOU ISCHEMICKOU CHOROBOU SRDEČNÍ A JEHO VLIV NA SYSTOLICKOU A DIASTOLICKOU FUNKCI LEVÉ KOMORY, TOLERANCI ZÁTĚŽE A PROGNÓZU NEMOCNÝCH

(SOUBOR PUBLIKACÍ)

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OBSAH

1. ÚVOD

1.1. PŘÍZNIVÉ ÚČINKY AEROBNÍHO TRÉNINKU

Příznivý vliv fyzické aktivity na kardiovaskulární systém je nesporný nejen u zdravých jedinců, ale i u nemocných s kardiovaskulárními chorobami. Již desítky let je známo, že pravidelná aerobní zátěž nemocným se srdečními chorobami zlepšuje kvalitu života, omezuje jejich symptomy a zejména snižuje mortalitu [1-9]. Děje se tak ovlivněním celé řady dějů v organismu. Zřejmě nejvýraznějším účinkem je příznivé ovlivnění rizikových faktorů ischemické choroby srdeční (ICHS) [10-11]. Je ovlivněn lipidový metabolismus snížením LDL (low-density lipoprotein) a zvýšením HDL (high density lipoprotein) cholesterolu [8, 12-14]. Pravidelnou tělesnou aktivitou dochází též ke zvýšení senzitivity k inzulinu, což spolu s dietními opatřeními vede k redukci obezity [8, 15]. Dalším efektem je ovlivnění humorální rovnováhy snížením klidové sympatikoadrenální aktivity [16]. Tento vliv spolu s omezením agregace krevních destiček a poklesem plazmatických hladin fibrinogenu vede ke snížení rizika vzniku akutního koronárního syndromu. Menší vzestup tepové frekvence (TF) a krevního tlaku (TK) při zátěži způsobuje pokles kyslíkových požadavků myokardu [17-20]. V neposlední řadě je příznivě ovlivněna i psychika nemocných [8].

Výše popsané účinky jsou více či méně společné pro jakoukoliv skupinu cvičících, ať už se jedná o primární prevenci zdravých jedinců nebo sekundární prevenci kardiologicky nemocných. U nemocných s ICHS jsou kromě zlepšení prognózy nemocných [21-23] očekávány i některé specifické efekty aerobního tréninku. Jde především o zmírnění anginózních potíží a objektivních známek ischemie myokardu při zátěžových testech - zvýšení tolerance zátěže, snížení incidence depresí ST úseku při zátěžovém testu nebo segmentární poruchy kontraktility při zátěžové echokardiografii, apod. [24-25]. Tyto změny mohou nastat několika mechanismy. Pravidelný trénink vede jednak snížení srdeční práce tím, že se na jedné straně sníží spotřeba kyslíku (snížením TF a TK) [7, 26-29] a zároveň dochází i ke zlepšení přísunu kyslíku (rozšířením epikardiálních koronárních artérií, zvýšením denzity myokardiálních kapilár a případným rozvojem kolaterál) [24, 30]. Kombinace pravidelného cvičení s dietou omezující tuky vede u nemocných s ICHS ke zpomalení progrese koronárních stenóz a podle některých prací může dokonce dojít až k jejich regresi [17, 28, 31-32].

1.2. TRÉNINKOVÉ REŽIMY

Z výše uvedeného je zřejmé, že by kardiovaskulární rehabilitace měla představovat nezbytnou součást komplexní léčby pacientů s ICHS. Je také součástí mnoha doporučení odborných společností. Aktuálně platná doporučení České kardiologické společnosti z roku 2006 [33] popisují u nemocných s ICHS rehabilitaci nemocných po infarktu myokardu (IM), kterou rozdělují na 4. fáze – nemocniční, časnou posthospitalizační, stabilizační a udržovací. Dále se zaobírají jinými kardiálními diagnózami. Nemocní s chronickou ICHS zde nejsou blíže rozvedeni. Novější doporučení Evropské kardiologické společnosti [34] rozebírají obecně nemocné se srdečními onemocněními s důrazem na nemocné po IM, aortokoronárních bypassech (CABG) nebo koronárních intervencích (PCI). Naproti tomu, americká doporučení American Heart Association [35] jsou zaměřena cíleně na nemocné s koronární nemocí. Podle těchto doporučení by všichni nemocní měli být povzbuzováni a motivováni k 30-60 minutám středně intenzivní aerobní aktivity nejméně 5 (nejlépe 7) dní v týdnu. Je vhodné tento aerobní trénink podpořit silovým cvičením alespoň 2krát týdně.

Ačkoliv je prospěšnost kardiovaskulární rehabilitace nezpochybnitelná, není zatím zcela vyjasněno přesné optimální nastavení tréninku. Struktura a intenzita doporučovaných a realizovaných tréninků se liší nejenom mezi jednotlivými zeměmi, ale i mezi centry. Odlišnosti jsou prakticky ve všech parametrech tréninku - intenzitě, frekvenci, trvání, obsahu tréninkové jednotky. Tomuto faktu odpovídá i výrazná nesourodost publikací ve světové vědecké literatuře s nemožností srovnaní dat z různých center a obtížemi stran praktických aplikací zjištěných výsledků [36-39]. Je jistě správné, aby nemocný měl (víceméně jakékoliv) navýšení hlavně aerobní aktivity, ale určitě v současné době existuje poměrně velký prostor pro snahy hledat optimální tréninkový režim.

Jakkoliv je hledání optimálního tréninkového modelu důležité, daleko větším aktuálním problémem je relativně malé procento nemocných, kteří se institucionálních tréninkových programů účastní. Příčiny jsou jak na straně medicínských zařízení, tak na straně pacientů. Ne každá nemocnice má k dispozici oddělení kardiovaskulární rehabilitace. A i v případech, že tato možnost existuje, jen málokde je celý systém natolik fungující, aby byli všichni nemocní osloveni a motivováni k absolvování tréninkových jednotek. A z těch, kterým účast nabídnuta je, jen menší část nemocných s absolvováním ambulantních cvičení souhlasí a opravdu ho celé absolvuje. Důvody jsou pestré, od principiální nechuti nemocného měnit svůj zavedený životní styl až po důvody ryze praktické, zahrnující například časovou náročnost, problémy s dopravováním se na trénink, apod. Pro tyto nemocné jsou ve světě hledány alternativy. Jednou z možností je takzvaná domácí rehabilitace, kdy nemocný není nucen dojíždět do centra, ale cvičí si sám doma. Domácí rehabilitace může být výhradním tréninkem nebo může navazovat na vstupní tréninkové jednotky v centru. Může být pod částečným dozorem (skrze telefonní kontakt nebo internet) nebo bez dozoru s následným zhodnocením při ambulantní kontrole nemocného [40-43]. Domácí rehabilitace má řadu výhod, ale také limitací. Mezi omezení patří zejména horší kontrola cvičení a omezená možnost pomoci nemocnému při případných nežádoucích účincích cvičení – proto nelze tento druh tréninku doporučit paušálně všem nemocným. K hlavním výhodám patří kromě již zmíněného vyřešení některých překážek absolvování cvičení i to, že pacient, který si zvykne na režim v domácích podmínkách, v tomto režimu snadněji setrvá v budoucnu. Dosud nejsou jednoznačná data srovnávající efekt řízeného a individuálního aerobního cvičení.

1.3. EFEKT KARDIOVASKULÁRNÍ REHABILITACE NA FUNKCI LEVÉ KOMORY (LK) SRDEČNÍ

Jak bylo uvedeno na začátku, existuje poměrně velké množství dat potvrzujících nejrůznější příznivé účinky kardiovaskulární rehabilitace. Oproti tomu máme k dispozici jen omezené množství informací o tom, zda trénink dokáže ovlivnit funkci LK. Výsledky dostupných prací u nemocných s ICHS jsou rozporuplné. Na jedné straně řada prací [44-47] nenašla žádný významný rozdíl mezi skupinami cvičícími a kontrolními. Na straně druhé, například Giannuzzi s kolektivem [48] zjistili zlepšení ejekční frakce (EF) LK a redukci nežádoucí remodelace LK u nemocných po Q IM a absolvování tréninku ve srovnání s kontrolami bez tréninku. Podobně Klecha a spol. [49] popsali trend ke zlepšení funkčních parametrů LK po šestiměsíčním tréninku nemocných s ICHS. Podobné výsledky publikovali i další autoři [50-51]. Podle velké metaanalýzy z roku 2011 [52] bylo nalezeno celkem 12 studií zkoumající efekt tréninku na EF LK u nemocných po IM. Metaanalýza potvrdila pozitivní efekt rehabilitace jak na vývoj EF LK, tak i na její remodelaci.

LK hodnocen pomocí EF LK a endsystolického a enddiastolického rozměru LK. Výhodou těchto parametrů je jejich snadná dostupnost a také fakt, že jsou rutinně používány. Naopak nevýhodou je, že jsou na sledování malých změn (a jiné se jistě při krátkých sledováních ani očekávat nedají) příliš hrubými parametry. Lze spekulovat o tom, že v studiích s negativním výsledkem mohl být příznivý efekt rehabilitace na funkci a remodelaci LK přítomný, ale natolik malý, že pomocí měřených parametrů prostě nebyl zachycen.

Novější echokardiografická metoda, tkáňová dopplerovská echokardiografie (TDI) je technika využívající dopplerovský princip k měření rychlosti pohybu myokardu. Pulsní TDI umožňuje výrazně přesněji kvantifikovat systolickou i diastolickou funkci LK [53-55]. Parametry TDI se tedy nabízí jako potenciálně výhodnější a přesnější k sledování zejména menších změn funkce LK v čase [56]. Pomocí pulsní TDI získáme křivku pohybu myokardu v měřeném místě. Měření lze provádět prakticky v jakémkoliv segmentu LK, ale pro praxi se nejlépe osvědčilo měření rychlostí myokardu na bazi jednotlivých stěn v těsné blízkosti mitrálního anulu. Vzhledem k fyziologickým principům srdeční kontrakce je měření v těchto místech obrazem funkce celé příslušné stěny. Regionální systolická funkce je pak hodnocena velikostí vlny Sa (nově označované jako S´), která ukazuje aktuální rychlosti myokardu během systoly. V diastole měříme (u pacientů se sinusovým rytmem) vlnu Ea (nově E´ nebo e´), která zachycuje rychlosti myokardu během fáze rychlého plnění komory, a vlnu Aa (A´nebo a´) odpovídající rychlosti myokardu v době kontrakce síně. K vlastnímu hodnocení diastolické funkce je pak použita buď velikost vlny Ea nebo poměr vln Ea/Aa.

Do této doby je v písemnictví jen velmi málo prací, které využívají pulsní TDI k hodnocení efektu kardiovaskulární rehabilitace na funkci LK. Jedna práce [57] popisuje zlepšení diastolické funkce hodnocené pomocí TDI u obézních mužů po osmitýdenním tréninku, další [58] zlepšení diastolické funkce LK po komplexní intervenci včetně tělesného tréninku u nemocných s ledvinným selháním. U nemocných s ICHS po IM, Deljanin-Ilic a spol. [59] popsali po tréninku zlepšení celkové i regionální funkce LK v místě IM.

1.4. CÍLE HABILITAČNÍ PRÁCE

(1) Srovnat parametry opakovaného ergometrického zátěžového testu nemocných s ICHS s řízeným a nekontrolovaným aerobním tréninkem.

(2) Zhodnotit vliv aerobního tréninku na systolickou a diastolickou funkci LK u nemocných s ICHS.

(3) Porovnat prognostický efekt různých typů tréninku.

Tyto cíle vyly řešeny v dílčích projektech, které jsou uvedeny v následujících kapitolách 2.1., 2.2., 2.3. a 2.4., a které byly úspěšně publikovány v recenzovaných kardiologických časopisech.

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2. VÝSLEDKY

2.1. SROVNÁNÍ ŘÍZENÉHO A NEKONTROLOVANÉHO AEROBNÍHO TRÉNINKU NEMOCNÝCH S CHRONICKOU ISCHEMICKOU CHOROBOU SRDEČNÍ

ABSTRAKT

Cíl: Cílem práce bylo srovnat parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční (ICHS) s řízeným a nekontrolovaným aerobním tréninkem.

Soubor pacientů a metodika: Šedesát čtyři nemocných s chronickou ICHS bylo rozděleno do 4 skupin podle intenzity a druhu aerobního tréninku. Do skupiny A bylo zařazeno 17 pacientů, kteří se zúčastnili řízeného tříměsíčního rehabilitačního programu a navázali na něj individuálním cvičením. Ve skupině B bylo 22 pacientů, kteří absolvovali jen řízený program bez následného individuálního tréninku. Ve skupině C bylo 10 pacientů, kteří neabsolvovali rehabilitační program, ale doma intenzivně cvičili. Do skupiny D bylo zařazeno 15 pacientů, kteří se nezúčastnili rehabilitačního programu, ani doma necvičili. Ergometrické testy byly provedeny před zařazením do studie a po 1 roce sledování. Byly hodnoceny změny těchto parametrů: celkový čas zátěže, celkově vykonaná práce, pracovní kapacita, pracovní tolerance, čas do stenokardií, deprese ST úseku ve svodu V5 při maximální zátěži.

Výsledky: Pro nemocné ve skupině C byl zjištěn trend ke zlepšení ve všech hodnocených parametrech s výjimkou prohloubení deprese úseku ST ve svodu V5 při maximální zátěži. Ve skupině A nemocní dosáhli delšího celkového času zátěže, vykonali větší celkovou práci a měli vyšší pracovní toleranci, v ostatních parametrech došlo ke zhoršení. Pacienti ze skupin B a D se zhoršili ve všech parametrech. Všechny rozdíly v jednotlivých skupinách ani mezi skupinami navzájem nebyly statisticky významné.

Závěry: Parametry opakovaného ergometrického testu nemocných podstupujících jednotlivé typy rehabilitačních programů se od sebe statisticky nelišily. Byl nalezen trend ke zlepšení zátěžových parametrů u skupin nemocných cvičících intenzivně a trvale doma a trend ke zhoršení u skupin individuálně necvičících, a to nezávisle na absolvování úvodního řízeného rehabilitačního programu.

Klíčová slova: Tělesný trénink - Ischemická choroba srdeční - Ergometrie

ÚVOD

Příznivý vliv fyzické aktivity na kardiovaskulární systém je nesporný nejen u zdravých jedinců, ale i u nemocných s kardiovaskulárními chorobami. Pravidelná aerobní zátěž nemocným se srdečními chorobami zlepšuje kvalitu života, omezuje jejich symptomy a snižuje mortalitu [1-8]. Děje se tak příznivým ovlivněním rizikových faktorů vzniku a progrese především ischemické choroby srdeční. Dochází k ovlivnění lipidového metabolismu snížením LDL a zvýšením HDL cholesterolu [5, 9-10]. Zvyšuje se také senzitivita k inzulínu a spolu s dietními opatřeními dochází k redukci obezity [5, 11]. Dochází ke snížení klidové sympatikoadrenální aktivity, což spolu se omezením agregace krevních destiček a poklesem plazmatických hladin fibrinogenu vede ke snížení rizika vzniku akutního koronárního syndromu.

U nemocných s ischemickou chorobou srdeční má pravidelné cvičení řadu příznivých účinků vedoucích ke zmírnění anginózních potíží i objektivních známek ischemie myokardu při zátěžových testech - zvýšení tolerance zátěže, snížení depresí ST úseku, atd. Tyto změny jsou způsobeny několika mechanismy - pravidelný trénink způsobuje jednak snížení srdeční práce tím, že se sníží spotřeba kyslíku (snížením tepové frekvence a krevního tlaku) [4, 12-16] a zároveň má vliv i na zlepšení přísunu kyslíku (rozšířením epikardiálních koronárních artérií, zvýšením denzity myokardiálních kapilár a rozvojem kolaterál) [17-18]. Při dostatečně intenzivní zátěži, spolu s redukcí ostatních rizikových faktorů, může dojít k zastavení progrese popřípadě i k mírné regresi angiografických změn na koronárních artériích [4, 13, 19-20].

Pro pacienty se hledají optimální druhy a režimy tréninku (např. aerobní trénink s posilováním nebo bez něj), různé frekvence a délky cvičení. Prakticky všechny práce hodnotící nejrůznější řízené tréninkové programy přinášejí důkazy o jejich příznivých efektech. Existuje ale i dostatek prací, které popisují zlepšení pacientů, kteří se o svůj pohybový režim starají více či méně sami Dosud chybí studie srovnávající řízený a individuálního nekontrolovaného aerobního cvičení. Proto bylo cílem této práce srovnat parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční s řízeným a nekontrolovaným aerobním tréninkem.

MATERIÁL A METODY

Do studie bylo zařazeno 64 nemocných s chronickou ischemickou chorobou, kteří splňovali následující kritéria: onemocnění koronárních tepen bylo ověřeno koronarografií (zúžení průměru lumina tepny ≥ 50% na alespoň 1 hlavní koronární tepně); bez anamnézy prodělané ataky nestabilní anginy pectoris nebo infarktu myokardu v posledních 3 měsících před zařazením do studie; bez anamnézy revaskularizace myokardu koronární angioplastikou nebo aortokoronárním bypassem v posledních 3 měsících před zařazením do studie; nepřítomnost významné chlopenní vady a destabilizované hypertenze. Všem nemocným byl opakovaně a důkladně vysvětlen příznivý účinek tělesné aerobní aktivity na jejich zdravotní stav, doporučena pravidelná aerobní aktivita a nabídnut tříměsíční řízený rehabilitační program. Všichni nemocní podstoupili ergometrický zátěžový test při zařazení do studie a po 1 roce sledování.

Zpětně byli nemocní rozděleni do čtyř skupin podle intenzity a druhu jejich aerobního tréninku. Do skupiny A bylo zařazeno 17 pacientů (14 mužů a 3 ženy, průměrného věku 66±11 let), kteří se zúčastnili řízeného rehabilitačního programu a doma na něj navázali individuálním cvičením. Ve skupině B bylo 22 pacientů (14 mužů a 8 žen, průměrného věku 66±8 let), kteří absolvovali jen řízený program bez následného individuálního tréninku. Ve skupině C bylo 10 pacientů (7 mužů a 3 ženy, průměrného věku 60±8 let), kteří neabsolvovali rehabilitační program, ale doma intenzivně cvičili. Do skupiny D bylo zařazeno 15 pacientů (12 mužů a 3 ženy, průměrného věku 63±8 let), kteří se nezúčastnili rehabilitačního programu, ani doma necvičili. Další charakteristiky jednotlivých skupin jsou uvedeny v tabulce 1. Rozdíly mezi jednotlivými skupinami nebyly statisticky významné. Farmakologickou léčbu nemocných ukazuje tabulka 2.

Tabulka 1. Charakteristika pacientů

Tab. 1. Charakteristiky pacientů.

skupina	počet	věk (roky)	nadváha (%)	HT (%)	DM (%)	DLP (%)	AP	IM (%)	počet tepen	CABG (%)	PTCA (%)	EF (%)
A	17	66	71	65	24	82	1,2	53	2,3	18	41	48
B	22	66	82	45	23	82	1,3	86	1,6	14	41	45
C	10	60	80	70	20	90	1,3	90	1,9	20	70	43
D	15	63	67	73	20	73	1,4	60	2,2	20	27	49

HT = hypertenze, DM = diabetes mellitus, DLP = dyslipoprotienemie, AP = stupeň anginy pectoris podle kanadské klasifikace (CCS), IM = počet nemocných po infarktu myokardu, počet tepen = průměrný počet tepen postižených významnou stenozou, CABG = počet nemocných po aorto-koronárním bypassu, PTCA = počet nemocných po perkutánní koronární angioplastice, EF = ejekční frakce levé komory.

HT = hypertenze; DM = diabetes mellitus; DLP = dyslipoproteinémie; AP = stupeň anginy pectoris podle kanadské klasifikace (CCS); IM = počet nemocných po infarktu myokardu; Počet tepen = průměrný počet tepen postižených významnou stenózou; CABG = počet nemocných po aorto-koronárním bypassu; PTCA = počet nemocných po perkutánní koronární angioplastice; EF = ejekční frakce levé komory

Tabulka 2. Charakteristika pacientů – farmakologická léčba nemocných

Tab. 2. Farmakologická léčba nemocných.

Skupina	salicyláty (%)	BB (%)	CaA (%)	nitráty (%)	ACEI (%)	ATII (%)	statiny (%)
A	100	94	53	53	53	12	88
B	95	100	27	68	68	0	82
C	90	100	10	70	70	10	80
D	100	93	40	80	33	0	73

BB = betablokátory, CaA = kalciový antagonisté, ACEI = antagonisté angiotenzin–konvertujícího enzymu, ATII = sartany.

BB = betablokátory; CaA = kalciový antagonisté; ACEI = antagonisté angiotenzin konvertujícího enzymu; AT II = sartany

Řízený rehabilitační program probíhal na Klinice funkční diagnostiky a rehabilitace Fakultní nemocnice U svaté Anny. Nemocní, kteří souhlasili s absolvováním tohoto programu, měli před jeho zahájením provedeno spiroergometrické vyšetření k nastavení úrovně aerobního cvičení. Vyšetření bylo provedeno v ranních hodinách při ponechané medikamentózní léčbě. Vlastní vyšetření začínalo tříminutovou adaptací vsedě na veloergometru. Následovaly dvouminutové zátěže od 20 W, zvyšované vždy o 20 W, v jejichž průběhu byly měřeny ventilačně-respirační parametry. Ty byly sledovány přístrojem Pulmonary Function System 1070 (Med Graphics, USA). Byl hodnocen symptomy limitovaný minutový příjem kyslíku (VO2) jako kritérium kardiorespirační funkční zdatnosti a byla určena hodnota anaerobního prahu k nastavení vhodné intenzity zatížení. Hodnota anaerobního prahu byla pro potřeby studie vyjádřena ve W, odpovídající hodnotě tepové frekvence a stupněm Borgovy škály subjektivního vnímání namáhavosti příslušného zatížení. Během celého vyšetření včetně doby restituce byl monitorován dvanáctisvodový elektrokardiogram (Schiller CS 100, USA), v klidu a na konci každé zátěže byl měřen krevní tlak.

Vlastní rehabilitační program trval 3 měsíce, během kterých nemocní cvičili 3x týdně 60 minut. Cvičební jednotka se skládala z fáze zahřívací (10 minut), vlastního aerobního cvičení na veloergometru na úrovni aerobního prahu doplněná silovým tréninkem (40 minut) a ze závěrečné fáze relaxační (10 minut) (Obr. 1).

Individuální aktivita byla doporučována jako minimálně 3krát týdně 60 minut aerobního cvičení (jízda na kole nebo na rotopedu, běh, plavání). Plnění tohoto doporučení bylo zjišťováno pouze anamnesticky od pacienta a nebylo ani kontrolováno, ani prověřováno.

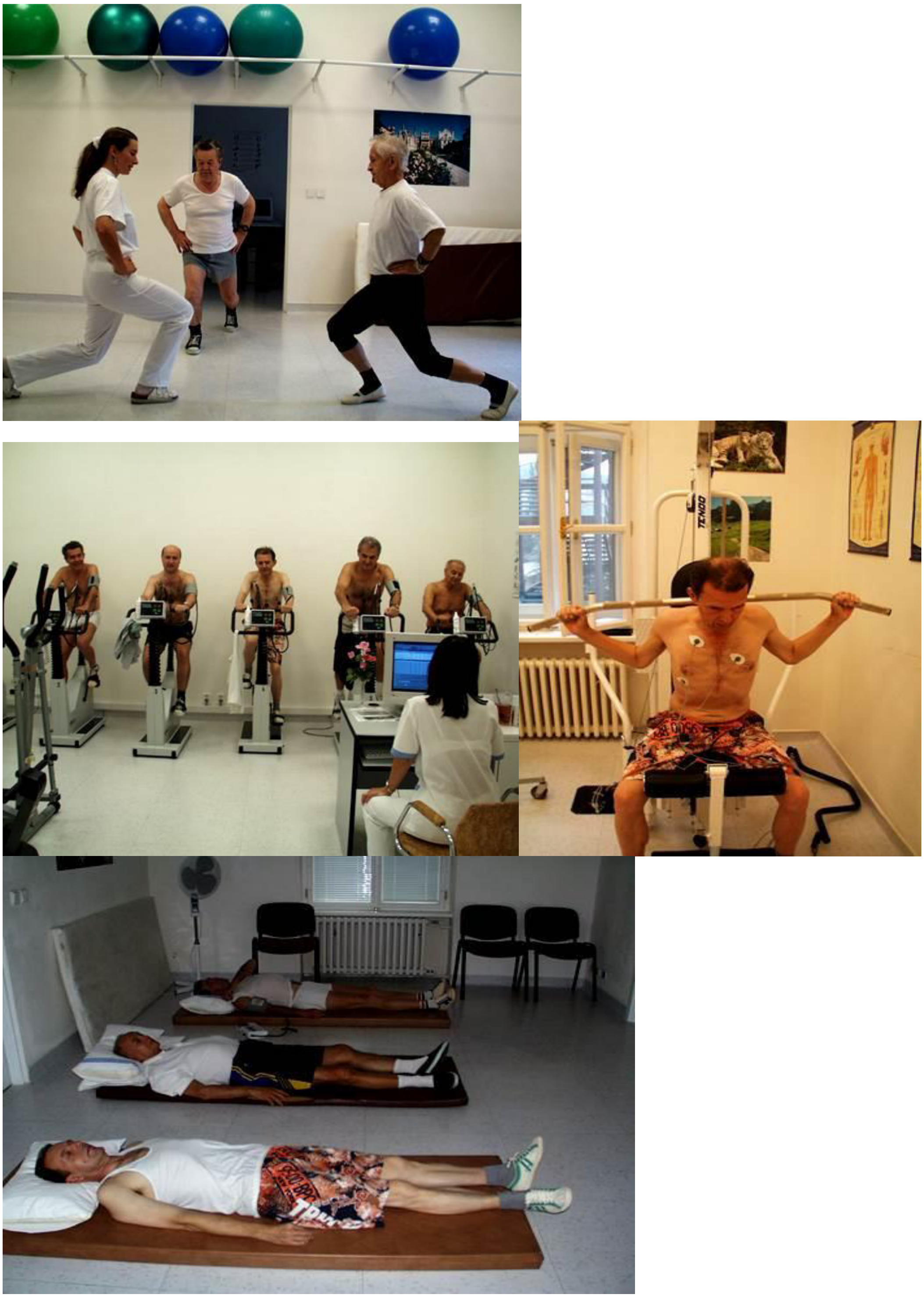
Ergometrické zátěžové testy byly provedeny na přístroji Ergo-line před zařazením do studie a po jednom roce sledování, vždy s vysazenou medikací. Bylo započato zátěží 0,5W/kg, která byla schodovitě zvyšována po 3 minutách vždy o 0,5 W/kg. Test byl ukončen při průkazu ischemie (objevení se nebo prohloubení depresí ST úseku o alespoň 0,2mV), při dosažení průměrné maximální tepové frekvence vzhledem k věku, při vzestupu krevního tlaku nad 250/130, při dosažení hranice subjektivního maxima. Rozdíl mezi zátěžovým testem na konci sledování a na začátku studie byl hodnocen pomocí změny těchto parametrů: celkový čas zátěže, celkově vykonaná práce, pracovní kapacita, pracovní tolerance, čas do stenokardií a deprese ST úseku ve svodu V5 při maximální zátěži (srovnáno dle maximální zátěže vstupního testu).

Ejekční frakce byla před zařazením do studie stanovena retrográdní levostrannou ventrikulografií.

Výsledky srovnání změny parametrů ergometrických testů nemocných jsou uvedeny jako průměry ± směrodatná odchylka. Výsledky jednotlivých skupin byly porovnány parametrickou statistickou metodou ANOVA. Hodnoty $p < 0,05$ byly považovány za významné. Normální rozložení hodnot bylo testováno pomocí Kolmogorov-Smirnovovým testem s výsledkem $p > 0.2$.

Obrázek 1. Rehabilitační program

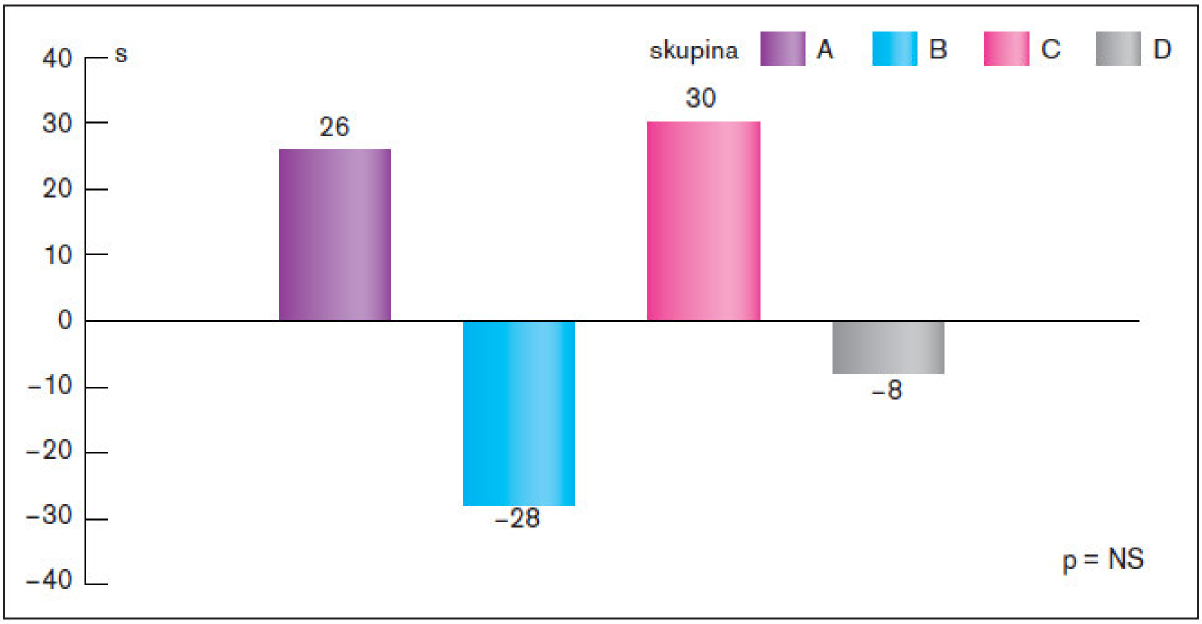
a- zahřívací fáze, b- aerobního cvičení na veloergometru, c- silový trénink, d- relaxační fáze



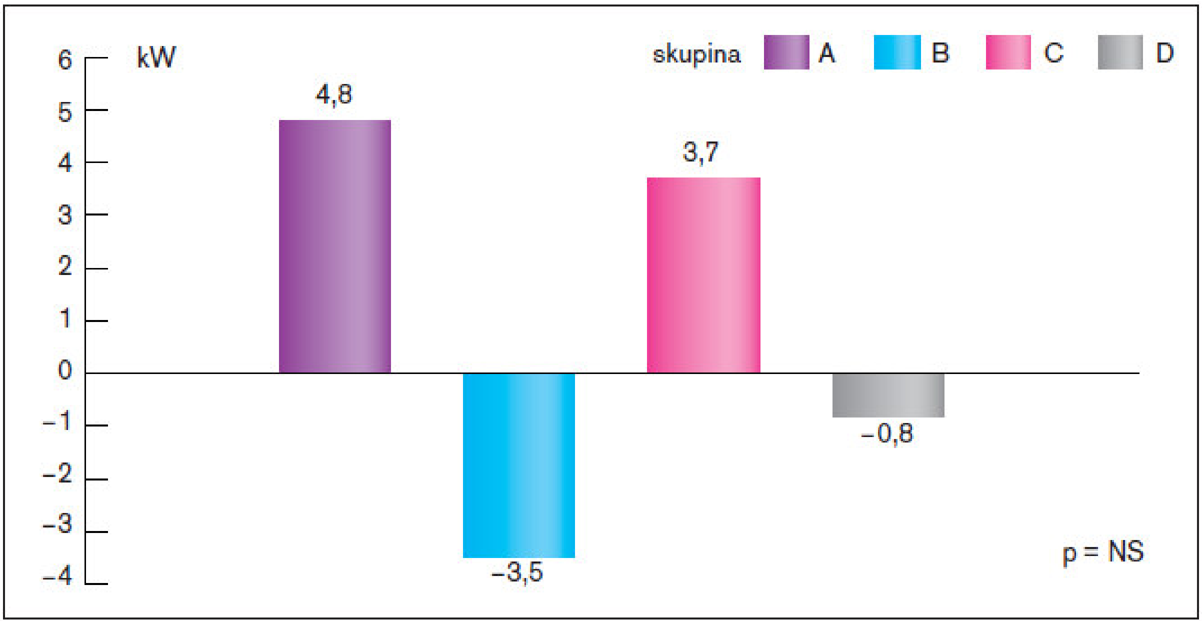
VÝSLEDKY

Vliv různých typů tréninku na změnu parametrů ergometrického zátěžového testu přehledně znázorňují grafy 1-6.

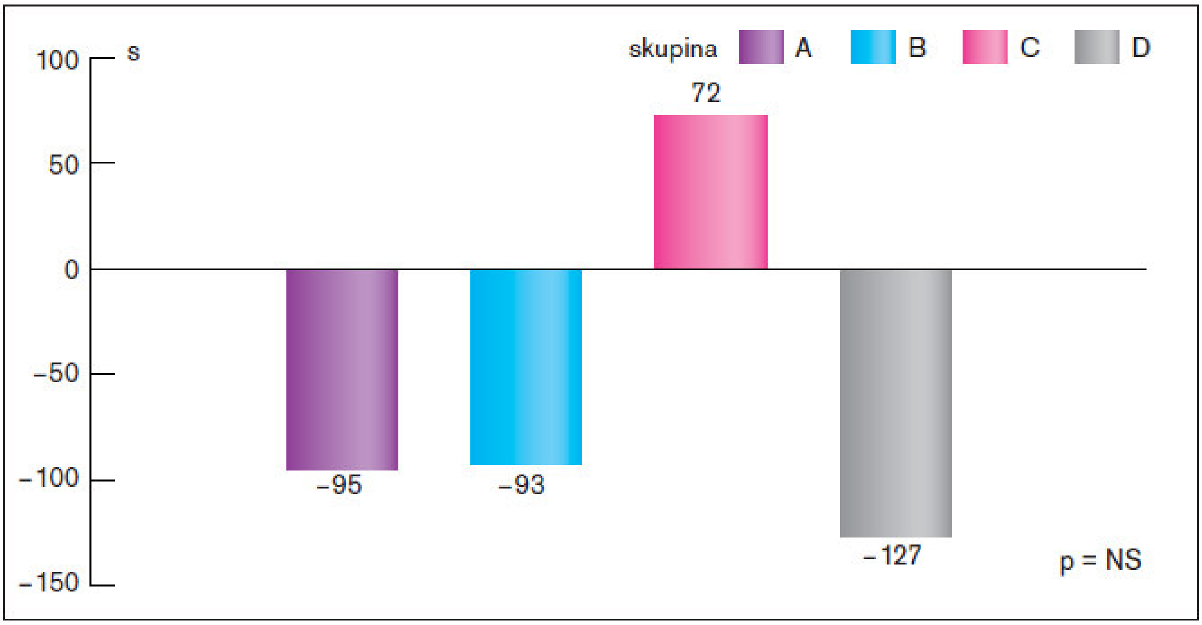
Graf 1. Srovnání změn celkového času zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.



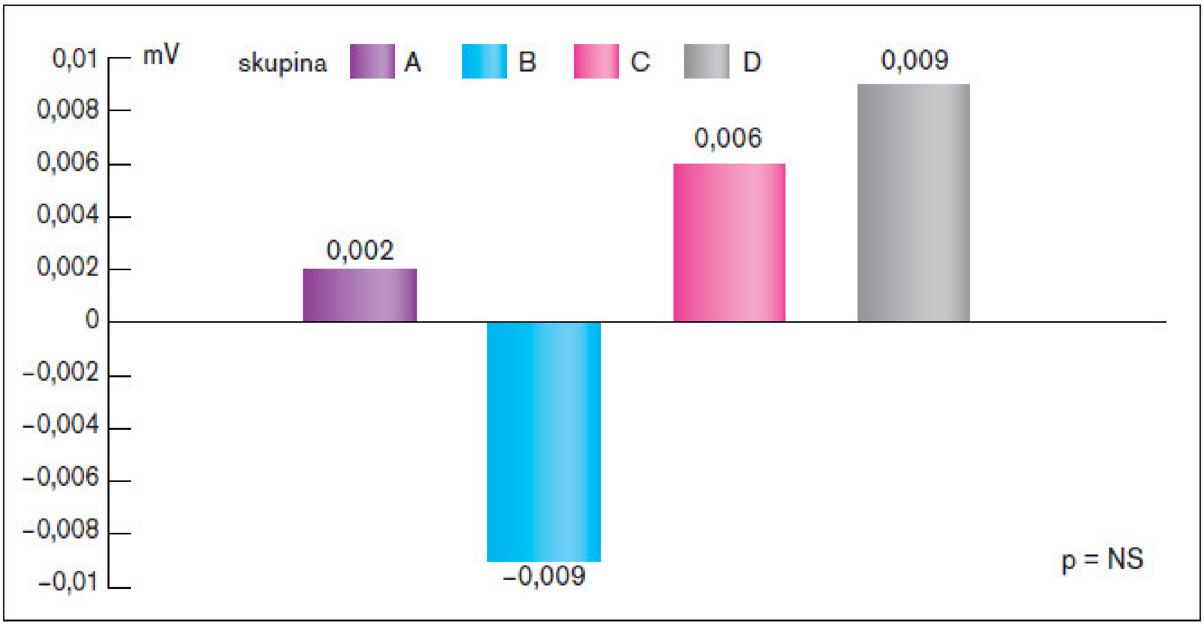
Graf 2. Srovnání změn celkové práce během zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách



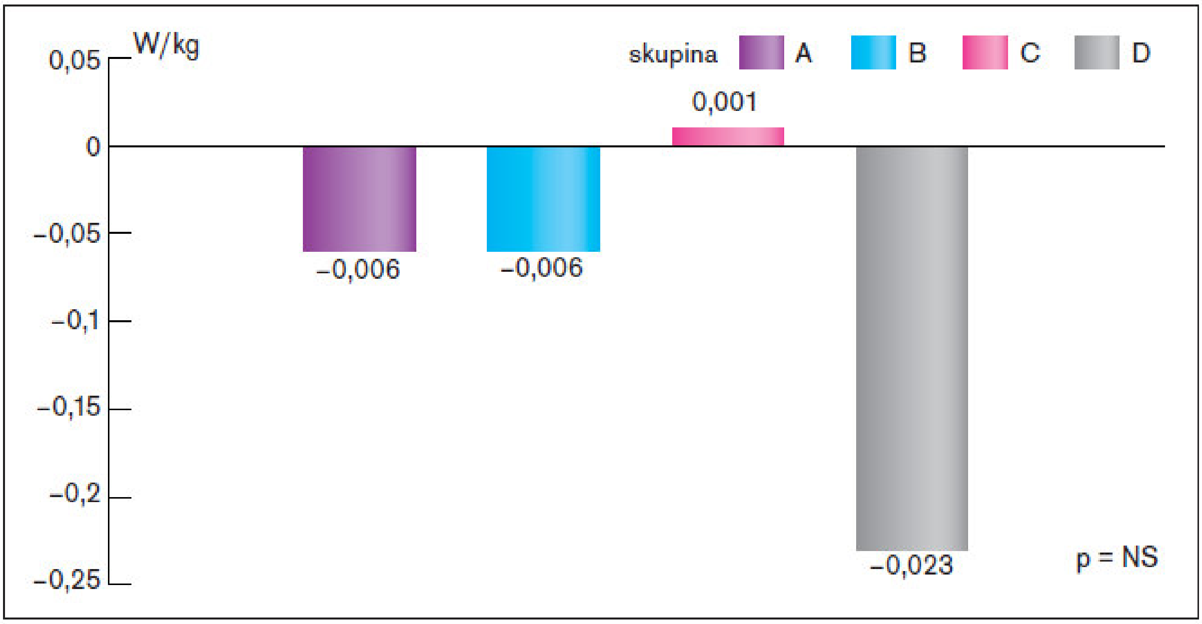
Graf 3. Srovnání změn času do stenokardií během zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách



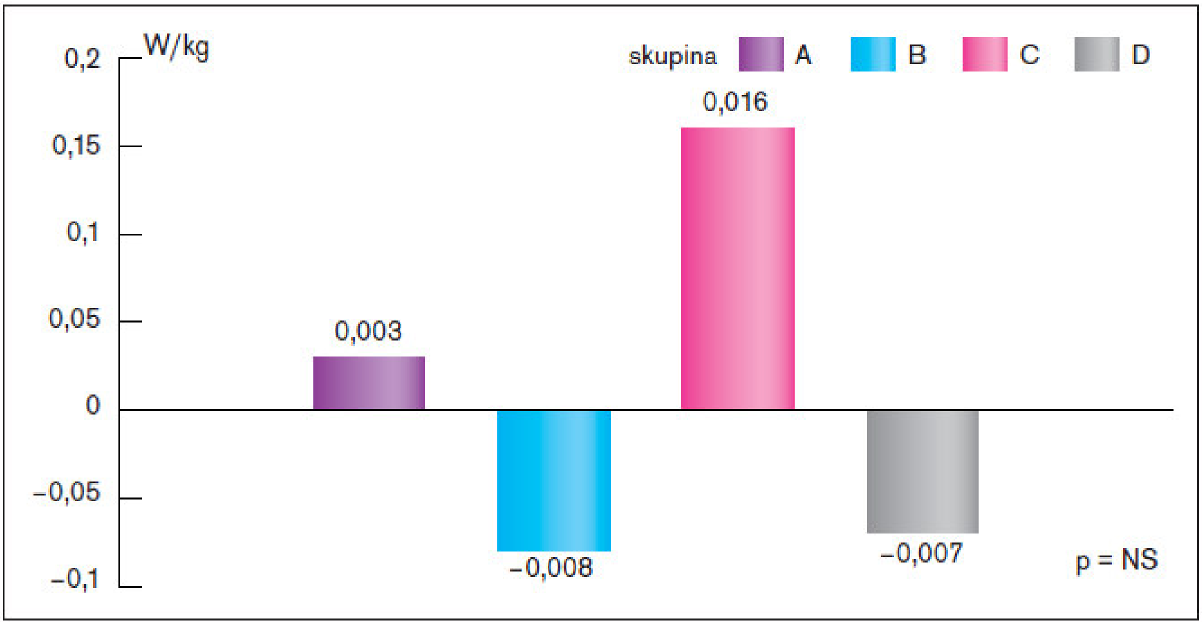
Graf 4. Srovnání změn depresí ST úseku ve svodu V5 při maximální zátěži na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách



Graf 5. Srovnání změn pracovní kapacity na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách



Graf 6. Srovnání změn pracovní tolerance na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách



Nalezené změny zátěžových testů v jednotlivých skupinách nedosáhly statistické významnosti. Nemocní cvičící od začátku individuálně (skupina C) měli trend ke zlepšení ve všech hodnocených parametrech s výjimkou prohloubení deprese úseku ST ve svodu V5 při maximální zátěži (prohloubení při kontrolním testu o 0,006±0,018mV – p=NS). Při kontrolním testu dosáhli o 30±108sec delší doby zátěže, vykonali o 3,7±15,0 kW větší celkovou práci, dosáhli vyšších hodnot pracovní kapacity o 0,01±0,52 W/kg a pracovní tolerance o 0,16±0,33 W/kg a prodloužil se u nich čas do stenokardií o 72±408 sekund (vše p=NS).

Nemocní, kteří absolvovali řízený program a následně individuálně cvičili (skupina A) dosáhli nevýznamně delšího celkového času zátěže (zlepšení o 26±73sec), vykonali větší celkovou práci (o 4,8±14,2 kW) a měli vyšší pracovní toleranci (o 0,03±0,36 W/kg) (vše p = NS). V ostatních parametrech došlo k mírnému zhoršení - pracovní kapacita poklesla o 0,06±0,48 W/kg, ST deprese ve svodu V5 při maximální zátěži se prohloubily o 0,002±0.014 mV a doba do vzniku stenokardií se zkrátila o 95±269 sec (vše p= NS).

Pacienti necvičí vůbec (skupina D) nebo necvičící po absolvování RHB programu (skupina B) se zhoršili prakticky ve všech sledovaných parametrech. Pacienti ve skupině B vydrželi kontrolní zátěžový test o 28±51 sec kratší dobu, vykonali o 3,5±5,9 menší celkovou práci, zhoršili svoji pracovní kapacitu o 0,06±0,28 W/kg a pracovní toleranci o 0,08±0,20 W/kg a stenokardie popisovali o 93±219 sec (vše p= NS). Menší deprese úseku ST ve svodu V5 o 0,009±0,018mV (p=NS) je dán menší celkovou prací při kontrolním testu.

Nemocní ze skupiny D měli nižší čas zátěže o 8±95 sec, menší celkově vykonanou práci o 0,8±13,3 kW, menší pracovní kapacitu o 0,23±0,36 W/kg a pracovní toleranci o 0,07±0,25 W/kg, stenokardie udávali o 127±320sec dříve a deprese úseku ST ve svodu V5 se prohloubily o 0,009±0,012 mV (vše p= NS).

Rozdíly mezi jednotlivými hodnocenými skupinami nebyly statisticky významné. Během obou sledovaných forem fyzického tréninku nenastala žádná závažná komplikace.

DISKUSE

V naší práci se parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční podstupující jednotlivé typy rehabilitačních programů od sebe statisticky významně nelišily. Počty nemocných a změny hodnocených parametrů nebyly dostatečně velké k dosažení statisticky významných rozdílů, nicméně byly nalezeny jasné trendy k většímu zlepšení zátěžové kapacity a tolerance u skupin nemocných cvičících intenzivně a trvale doma a to nezávisle na absolvování řízeného rehabilitačního programu.

Nebylo překvapením, že se zlepšili právě pacienti, kteří se cvičení věnují intenzivně sami. Mírně překvapil fakt, že se na výsledcích více neprojevil vstupní řízený trénink. Je tomu tak, pravděpodobně, z důvodů provedení kontrolních testů až 9 měsíců po ukončení řízeného tréninku. Je známo, že čím je trénink více intenzivní, tím se dá očekávat výraznější efekt na zátěžovou toleranci [21]. Zatímco u nemocných, kteří po absolvování programu pokračovali ve cvičení, se při kontrolních testech projevil hlavně intenzivní dlouhodobý trénink. Naopak, ti pacienti, kteří cvičit přestali, měli své funkční parametry na úrovni, jako kdyby necvičili vůbec.

I v ostatních studiích zaměřených na tuto problematiku v minulosti byly nalezeny vlivy pravidelného cvičení na zátěžové parametry. Studie European Heart Failure

Training Group [22] uvádí statisticky významné 17% zvýšení celkového času zátěže u pravidelně cvičících pacientů a to bez rozdílu zda účastníci cvičili doma nebo v nemocnici. Také udává větší účinnost u kombinace cvičení na ergometru a rytmiky oproti samotnému cvičení na ergometru.

Benzer a spol. [23] zjistili významné zlepšení stavu (sledované pomocí dotazníku kvality života) po 1-měsíčním cvičení oproti nemocným, kteří necvičili. Zlepšení se sice týkalo jak nemocných cvičících pod dozorem v nemocnici, tak i těch, kteří cvičili individuálně mimo nemocnici, ale individuálně cvičící se zlepšili více. Autoři doporučují nemocným podstupující nemocniční trénink, aby následně navázali individuální aktivitou. Individuální tělesnou aktivitou se zabývali i Adachi a spol. [24], kteří zkoumali vliv různých intenzit tréninku na funkci levé komory. Jejich pacienti cvičili doma – jejich úkolem bylo chodit rychlou chůzí 15 minut 2x denně, 5 dní v týdnu, po dobu 2 měsíců. Intenzitu zátěži si řídili podle tepové frekvence. U 29 nemocných po infarktu myokardu prokázali, že trénink jakékoliv intenzity zlepšuje pracovní kapacitu, ale pouze trénink o vysoké intenzitě zlepšuje funkci levé komory vyjádřenou tepovým objemem a ejekční frakcí. I jiné studie prokázali, že čím je trénink intenzivnější, tím větší je jeho kardioprotektivní účinek [25-26].

Na poměrně velkém souboru 113 pacientů s ICHS, kteří cvičili pravidelně denně doma na rotopedu a své cvičení si zapisovali do přiděleného log-booku, Niebauer se spolupracovníky [13] prokázali po 6 letech sledování 28% zvýšení pracovní kapacity a zpomalení progrese koronárních stenóz. K podobným výsledkům dospěli i další studie [27]. Hledají se také nejrůznější možnosti, jak zvýšit motivaci pacientů ke cvičení a zároveň umožnit lékaři přesnější sledování fyzické aktivity – kromě zmíněného log-booku je možno využít například krokoměr nebo akcelerometr [28-30]. Pravidelné cvičení neovlivňuje pouze fyzickou výkonnost, ale i celkovou kvalitu života. Focht se spolupracovníky [31] porovnávali 2 druhy tělesného tréninku (pouze řízený versus řízený následovaný individuálním cvičením) u 147 osob starších 50 let a dle dotazníků zjistili zlepšení kvality života (health-related quality of life) při obou typech tréninku.

Naše práce, ve shodě s výše uvedenými studiemi, ukazuje, že nejdůležitější je pravidelnost a kontinuita cvičení. Řízené rehabilitační programy mají přesto několik nezastupitelných úloh. Ukazují nemocným styl cvičení, posilováním jim umožňují dosáhnout lepší fyzické kondice, která je nutná pro další pokračování ve cvičení na dostatečné úrovni zátěže doma. Velmi významná je u pacientů, u kterých hrozí zdravotní komplikace už při malém stupni zátěže a je u nich velké riziko zdravotních komplikací, které vyžadují lékařský dohled popřípadě intervenci. Jedno z možných řešení, jak spojit řízenou a individuální tělesnou aktivitu, naznačují němečtí autoři z Heidelbergu – jejich pacienti cvičili nejdříve 3 týdny intenzivně v nemocnici (6x denně!), následně jim byl zapůjčen rotoped a cvičili individuálně doma (2x denně po 30 minutách) s pravidelnými společnými cvičeními v nemocnici (2x týdně). Tímto velmi intenzivním tréninkem dosáhli u svých pacientů za 12 měsíců nejenom snížení zátěží vyvolané ischemie o 54% [32], ale prokázali i zpomalení progrese koronární aterosklerózy [20]. Rovněž zastavení progrese koronárních aterosklerotických lézí prokázali Hambrecht a spol. [33] u 29 chronických ischemiků pomocí 12-měsíčního individuálního tréninkového programu (minimálně 30 minut denně jízdy na ergometru) zahájeného 3 týdny společného cvičení v nemocnici (6x denně 10 minut šlapání na ergometru).

Podobně Hofman-Bang [4] nabídli svým pacientům 12 měsíční individuální tréninkový program spojený s pokusem o změnu životního stylu, který zahrnoval vstupní 4-týdenní „zaučení“. Na 151 nemocných po PTCA (perkutánní transluminální koronární angioplastice) ukázali zvýšení pracovní kapacity a snížení počtu hospitalizací během následujících 12 měsíců po ukončení programu. Z hlediska praktického využití mají tyto rehabilitační modely zásadní limitaci ve vstupní tří-, respektive čtyřtýdenní hospitalizaci, nicméně jistě by se podobné spojení řízené a individuální aktivity dalo přizpůsobit reálným možnostem a komfortu pacientů.

Hlavními limitacemi naší práce je malé množství nemocných v jednotlivých skupinách a krátká doba sledování. Spolu s očekávaně nevelkými změnami jednotlivých ergometrických parametrů po 1 roce sledování se nedá předpokládat statistická významnost rozdílů mezi skupinami.

ZÁVĚR

Parametry opakovaného ergometrického zátěžového testu nemocných podstupující jednotlivé typy rehabilitačních programů se od sebe statisticky významně nelišily. Byl nalezen trend zlepšení zátěžových parametrů u skupin nemocných cvičících intenzivně a trvale doma a trend zhoršení u skupin individuálně necvičících, a to nezávisle na absolvování úvodního řízeného rehabilitačního programu. Je třeba dbát zvýšeného důrazu na informování a edukaci nemocných s ICHS ve smyslu zintenzivnění jejich pohybového režimu.

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2.2. THE EFFECT OF REGULAR PHYSICAL ACTIVITY ON THE LEFT VENTRICLE SYSTOLIC FUNCTION IN PATIENTS WITH CHRONIC CORONARY ARTERY DISEASE

SUMMARY

Objective: The purpose of this study was to assess the influence of aerobic training on the left ventricular (LV) systolic function.

Methods: Thirty patients with stable coronary artery disease, who had participated in the conducted 3-month physical training, were retrospectively divided into 2 cohorts. While patients in the cohort I (n=14) had continued training individually for 12 months, patients in the cohort II (n=16) had stopped training after finishing the conducted program.

Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training program and 1 year later. The peak systolic velocities of mitral annulus (Sa) were assessed by tissue Doppler imaging for individual LV walls. In addition, to determine global LV systolic longitudinal function, the four-site mean systolic velocity was calculated (Sa glob).

According to the blood supply, left ventricular walls were divided into 5 groups: A- walls supplied by nonstenotic artery; B- walls supplied by coronary artery with stenosis ≤ 50%; C- walls supplied by coronary artery with stenosis 51-70%; D- walls with stenosis of supplying artery 71-99%; and E- walls with totally occluded supplying artery.

Results: In global systolic function, the follow-up values of Sa glob in cohort I were improved by 0.23±0.36 as compared with baseline values at rest, and by 1.26±0.65 cm/s at the maximal load, while the values of Sa glob in cohort II were diminished by 0.53±0.22 (p=NS), and by 1.25±0.45 cm/s ($p<0.05$), respectively.

Concerning the resting regional function, the only significant difference between cohorts in follow-up changes was found in walls E: 0.37±0.60 versus -1.76±0.40 cm/s ($p<0.05$). At the maximal load, the significant difference was found only in walls A (0.16±0.84 versus -2.67±0.87 cm/s; $p <0.05$).

Conclusion: Patients with regular 12-month physical activity improved their global left ventricle systolic function mainly due to improvement of contractility in walls supplied by a totally occluded coronary artery.

Key words: coronary artery disease – aerobic training - left ventricle systolic function

ABBREVIATIONS

ACE - angiotensin-converting enzyme

CR – cardiac rehabilitation

EF - ejection fraction

DM - diabetes mellitus

LV – left ventricle

MI - myocardial infarction

TDI – tissue Doppler imaging

2D - two-dimensional

Sa – peak systolic velocity of myocardium adjacent to the mitral annulus

Sa´- peak velocity of myocardium adjacent to the mitral annulus during isovolumic contraction

Ea – peak velocity of myocardium adjacent to the mitral annulus during early diastolic phase

Aa – peak velocity of myocardium adjacent to the mitral annulus during atrial contraction

INTRODUCTION

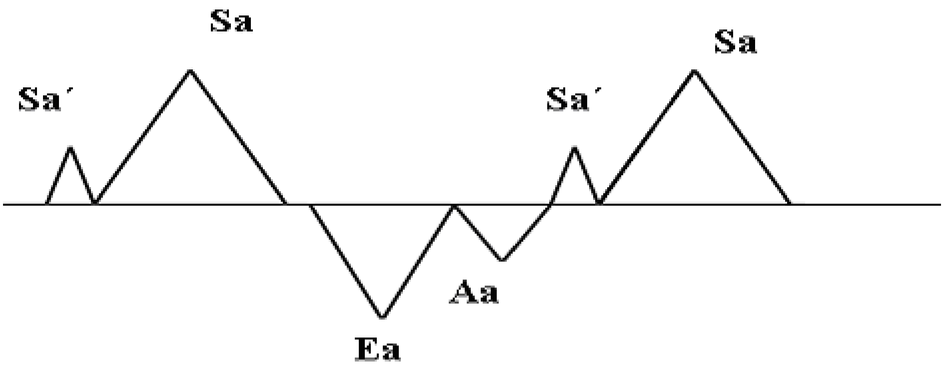
Beneficial effects of cardiac rehabilitation (CR) on secondary prevention of patients with coronary artery disease are now well-established. The major objective benefits are an increased exercise capacity (Hambrecht et al. 2000) and reduced rates of cardiac events and mortality (Oldridge et al.1988, Hadkell et al.1994). In addition, beneficial effects on coronary risk factors – blood pressure, lipid levels, glucose metabolism, body weight, as well as on the endothelial function and psychological well-being were proved (Shephard and Balady 1999).

On the other hand, only limited data exists concerning the effect of CR on left ventricular (LV) function. Some authors suggest improvements in cardiac function (Klecha et al. 2007, Hambrecht et al. 2000, Belardinelli et al.1996, Giannuzzi et al.1997), whereas others have not found any significant differences between exercise training groups and controls (Dubach et al.1997, Giannuzzi et al.2003). The different results may be due to differences in intensity and duration of training, measurement techniques or patient populations. However, in majority of the studies, LV function has been evaluated by LV ejection fraction (EF) measurements. It is well known that LVEF quantification using standard two-dimensional (2D) echocardiography is strongly dependent on image quality and endocardial border delineation.

Tissue Doppler imaging (TDI) is an echocardiographic technique employing the Doppler principle to measure the velocity of myocardium. Using the pulsed TDI we get the characteristic curve, which consists of three main waves (Figure 1). The positive Sa wave represents a systolic phase of cardiac cycle. This wave is frequently two-phased with the first slim peak of isovolumic contraction (Sa′) and second wider wave of ejection of LV. The first negative wave after the Sa wave is called Ea, it represents fast filling of the ventricle in diastolic phase of cardiac cycle. The second negative wave (Aa) grows from atrium contraction at the end of the diastolic phase of cardiac cycle. Pulsed-TDI permits quantification of regional longitudinal myocardial velocities with high temporal resolution and is feasible even in poor acoustic windows. Hence, TDI offered a potentially more accurate quantitative assessment of both regional and global LV function including even more minor changes in systolic LV function that are not detectable during 2D echocardiographic evaluation of LVEF.

The purpose of this study was to assess the influence of aerobic training on the LV systolic function using TDI measurements.

Figure 1. Characteristic curve of pulse TDI



Sa – peak systolic velocity of myocardium adjacent to the mitral annulus

Sa´- peak velocity of myocardium adjacent to the mitral annulus during isovolumic contraction

Ea – peak velocity of myocardium adjacent to the mitral annulus during early diastolic phase

Aa – peak velocity of myocardium adjacent to the mitral annulus during atrial contraction

PATIENTS AND METHODS

Patient population and study protocol

The study comprised 30 patients with stable coronary artery disease (proved by the coronary angiography performed before the study). All of them had participated in the conducted 3-month physical CR training. The continuation of physical training was recommended to all patients. After 1 year period, these patients were retrospectively divided into 2 cohorts. While patients in the cohort I (n=14) had continued training individually for 12 months, patients in the cohort II (n=16) had stopped training after finishing the conducted CR program.

Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training program and 1 year later. For the evaluation of regional systolic LV function, the pulsed TDI was used.

According to the blood supply, LV walls were divided into 5 groups: A- walls supplied by nonstenotic artery; B- walls supplied by coronary artery with stenosis ≤ 50%; C- walls supplied by artery with stenosis 51-70%; D- walls with stenosis of supplying coronary artery 71-99%; and E- walls with totally occluded supplying artery.

The study was in accordance with the Declaration of Helsinki (2000) of the World Medical Association, was approved by the institutional ethics committee and written consent was obtained from each patient.

Physical training

All patients had participated in the conducted outpatient CR. The program offered 3 months of 3 times per week sessions. Each session lasted for 60 minutes and consisted of 3 different phases: 10 minutes warm-up, period of aerobic exercise on bicycle ergometer with load intensity at the level of anaerobic threshold (20 minutes), period of resistance training performed on combined training machine (20 min), and relaxation period (10 min). Aerobic exercise intensity was individually prescribed according to symptom-limited spiroergometry (Blood Gas Analyser, MedGraphics, USA) that was provided before training period for the evaluation of anaerobic threshold.

The 9-months individual training of cohort I consisted of regular physical activity performed for a minimum of one hour at least three times a week. As a regular physical activity the patients have been asked to choose either cycling, riding a velo-ergometer or swimming.

Echocardiography

Using commercially available equipment Philips Sonos 5500 (Andover, USA) with a 2.5MHz transducer, echocardiographic examinations were performed in one centre by one experienced echocardiographer. 2D images of standard views and pulsed TDI of apical 4- and 2-chamber views were acquired and recorded on videotape for off-line analyses. The peak systolic velocities of myocardium adjacent to the mitral annulus (Sa) were assessed by TDI for individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine global LV systolic longitudinal function, the four-site mean systolic velocity was calculated (Sa glob). Velocities were evaluated at rest and at the maximal load.

Dobutamine echocardiography was performed in all patients. Dobutamine was infused with mechanical pump, starting at a dose of 5 µg/kg/min. At 3-minute intervals, the dose was increased incrementally to 10, 20, 30, 40 µg/kg/min until a maximal dose was reached or target heart rate was attained. Intravenous atropine was given in one bolus dose of 0.5mg if the target heart rate was not reached. After the test has been terminated, patients were monitored until baseline condition returned.

Statistical analysis

The changes of global and regional systolic function of individual LV wall groups were compared between cohorts at rest and at the maximal load. To assess normal distribution of variables, the Kolmogorov-Smirnov test was used. An unpaired t-test and Mann-Whitney U test were applied to compare the values of parameters between cohorts; $p<0.05$ was considered statistically significant.

RESULTS

Baseline characteristics and coronary angiography findings of patients are shown at Table 1 and 2. The majority of parameters have been similar in the two groups – just differences between the number of men and women and the difference between patients age in both cohorts have been found. No serious adverse events were found in either group during the follow-up.

Table 1. Characteristics of the study population

Parameter	**Cohort I**	**(n = 14)**	**Cohort II (n = 16)**	
Age (years)	60	(10)	69*	(8)
Men	13	(93 %)	8*	(50 %)
Diabetes mellitus	4	(29 %)	5	(31 %)
Hypertension	14	(100 %)	16	(100 %)
Hyperlipidemia	14	(100 %)	15	(94 %)
Previous myocardial infarction	10	(71%)	9	(57%)
LV EF (%)	50.4	(2.9)	47.9	(2.7)
No of stenotic arteries (≥70%)	2.1	(0.2)	1.6	(0.2)
Medication				
Aspirin	14	(100 %)	15	(94 %)
Beta blocker	14	(100 %)	16	(100 %)
ACE inhibitor	10	(71 %)	11	(70 %)
Statin	13	(93 %)	16	(100 %)
Diuretics	4	(29 %)	5	(31 %)
Nitrates	8	(57 %)	11	(69%)

The values are expressed as the mean supplied by standard error (in parentheses) or number (%) of subjects.

LV = left ventricle; EF = ejection fraction; No = number; ACE = angiotensin-converting enzyme; * p< 0.05 between cohorts

Table 2. Coronary angiography finding in cohorts

Cohort	I (n = 14)			II (n= 16)		
	LAD	LCX	RCA	LAD	LCX	RCA
no stenosis	3 (21%)	2 (14%)	3 (21%)	3 (19%)	6 (38%)	5 (31%)
stenosis ≤ 50	4 (29%)	7 (50%)	0 (0%)	2 (13%)	4 (25%)	4 (25%)
stenosis 51-70%	2 (14%)	2 (14%)	3 (21%)	1 (6%)	1 (6%)	2 (13%)
stenosis 71-99%	3 (21%)	1 (7%)	3 (21%)	4 (25%)	3 (19%)	2 (13%)
totally occluded	2 (14%)	2 (14%)	5 (36%)	6 (38%)	2 (13%)	3 (19%)

The values are expressed as number of arteries (%)

LAD = left anterior descending artery; LCX = left circumflex; RCA = right coronary artery

The changes of Sa value after follow-up in different groups of LV walls are shown in Table 3. In global systolic function, the values of Sa glob in cohort I were improved by 0.23±0.36 as compared with baseline values at rest, and by 1.26±0.65 cm/s at the maximal load, while the values of Sa glob in cohort II were diminished by 0.53±0.22 (p=NS), and by 1.25±0.45 cm/s ($p<0.05$), respectively.

Concerning the resting regional function, the only significant difference between cohorts in follow-up changes was found in walls E: 0.37±0.60 versus -1.76±0.40 cm/s ($p<0.05$). At the maximal load, the significant difference was found only in walls A (0.16±0.84 versus -2.67±0.87 cm/s; $p <0.05$). Sa changes in other walls was not significant.

Table 3. Changes of Sa value after follow-up in different groups of LV walls at rest and at the maximal load

Cohort	At rest I (n = 14)	II (n = 16)	At the maximal load I (n = 14)	II (n = 16)
Wall group				
A	-1.56±0.93	-0.86±0.38	0.16±0.84	-2.67±0.87*
B	1.29±0.63	0.62±0.58	3.83±1.13	0.56±1.05
C	-0.64±0.69	0.14±0.88	-0.42±1.02	-0.58+1.92
D	-0.09±0.86	-0.10±0.30	-2.82±1.19	-2.29±0.86
E	0.37±0.60	-1.76±0.40*	1.70±1.43	0.02±0.78
All (global function)	0.23±0.36	-0.53±0.22	1.26±0.65	-1.25±0.45*

The values are expressed as the mean supplied by standard error (in parentheses)

Sa = peak systolic velocity of mitral annulus; LV = left ventricle;

Wall groups : A- walls supplied by nonstenotic artery; B- walls supplied by artery with coronary stenosis ≤ 50%; C- walls supplied by artery with stenosis 51-70%; D- walls with stenosis of supplying artery 71-99%; and E- walls with totally occluded supplying artery.

* $p< 0.05$ between cohorts.

DISCUSSION

Effect of CR on global LV systolic function

The present investigation suggests that long-term exercise training can improve LV systolic function in patients with coronary artery disease. Previous works have shown variable results in relation to influence of CR on the LV function (Klecha et al.2007, Hambrecht et al.2000, Belardinelli et al.1996, Giannuzzi et al.2003). The failure to assess changes in LVEF in some studies may have several reasons. It may be the result of different study populations, kind and intensity of the training programs or the measurement techniques (Webb-Peploe et al.2000). Only patients with chronic heart failure or after myocardial infarction with moderate-to-severe LV dysfunction were included in the majority of studies assessing the influence of CR on LV function. In comparison with them, our patients had only slight depression of LVEF and not all of them underwent clinical myocardial infarction.

The intensity and duration of CR necessary for LV function improvement have not yet been sufficiently evaluated. In the analysis in the work of Piepoli (Piepoli 2004) the data suggested that only long-term duration over 28 weeks of CR may be required to reach benefits in mortality and adverse events rates. The antiremodelling effect of training with a trend towards improvement of LV functional parameters was found after 6-month training in the work of Klecha et al (Klecha et al.2007). On the other hand, the work of Hambrecht (Hambrecht 2000) demonstrated that an intense CR program can improve resting LVEF in 2 weeks. In our work, just 1-year CR improved LV systolic function, while the 3-month training did not provide the sustained long-term functional improvement.

The utilization of LVEF, as an evaluated parameter of LV function, could be one of the main factor contributing to the failure of some previous studies to shown the effect of CR. LVEF is a load-dependent parameter and is very rough to assess expected slight changes of LV function. EF evaluated by 2D echocardiography is strongly dependent on image quality and endocardial border delineation. In contrast, TDI is robust, reproducible and may be more sensitive marker of LV longitudinal systolic function and it is feasible even in poor echocardiographic windows. Hence, TDI allows evaluation of even minor changes in LV function that are not detectable by 2D assessment. In several published data, TDI has been applied to stress echocardiography in order to overcome the limitation of only visual analysis (Cain et al.2001, Fathi et al.2001, Bougault et al.2008, Duzenli et al.2008, Garcia et al.2006).

Effect of CR on regional LV systolic function

This present study is the first trial to evaluate the effect of CR on regional LV systolic function in relation to blood supply of individual LV walls. TDI was chosen for this purpose, because it permits quantification of regional longitudinal myocardial systolic velocities with a high temporal resolution and can overcome the limitation in the subjective echocardiographic evaluation of regional ventricular function (Reuss et al.2005).Our data showed that the effect of CR on LV systolic function is caused mainly through the improvement of contractility in walls supplied by a totally occluded coronary artery. The effect of physical training and LV global and regional function was assessed by TDI also in the study of Deljanin-Ilic and al (Deljanin-Ilic et al.2007). After 6 months, LV EF increased significantly as well as the regional systolic myocardial function at the previously infarcted wall only in the training group.

Mechanisms of this training effect have not yet been established. The most likely explanation is the combination of beneficial changes in ventricular wall tension and favorable adaptation in the coronary circulation. The physical training may have beneficial effect on changes in autonomic balance toward a vagal predominance, which could limit the deleterious effects of sympathetic hyperactivity on the LV remodeling and function, analogously to treatment with beta blockers.

In patients with stable coronary artery disease, augmented delivery of blood to ischemic myocardium has been shown to take place in response to physical training (Hambrecht 2004). The beneficial effect of CR on morbidity and mortality has been attributed to the growth of collateral vessels between healthy and underperfused myocardial regions (Shephard and Balady 1999). This theory was documented for example by work of Zbinden et al where beneficial dose-response effect of 3-month endurance exercise training on collaterals has been found (Zbinden et al.2007). However, other human studies have failed to document consistently the formation of collaterals. The main reason for different results may have been the lack of sensitivity of angiography to detect small coronary collaterals. The collateral growth and other coronary vascular changes may improve function of chronically hypoperfused myocardium.

Furthermore, CR has been shown to favourably affect blood flow rheology, thereby possible improving of myocardial perfusion. The improvement in myocardial blood flow to the infarcted area may lead to recovery of both global and regional LV function (Schuler et al.1992).

Although our study cannot elucidate the possible mechanism of regional functional improvement, we speculate, that combination of autonomic system changes and especially the development of collaterals may have facilitated partial functional recovery of dysfunctional but viable myocardial regions supplied by a totally occluded coronary artery.

Study limitations

Our study had several limitations. The study was retrospective, not randomized. The interpretations of results could be limited by a relatively small sample size in both cohorts. Also our study can be influenced by the difference between the number of men and women and the difference between patients age in both cohorts, because age and gender are determining factors for training effects - smaller improvements of women as well as a negative relation between age and improvement in exercise performance is known (Vanhees et al.2004).

Another limitation is the fact, that the 9-months training of cohort II have been performed as an outpatient individual training without any supervision. The information about frequency and intensity has been obtained only from patient's anamnesis during their regular visits in outpatient department. However, very different types of training programmes are described in literature and in some studies, a home-based CR had no significant differences in the main outcomes compared with the centre-based programme (Jolly et al.2009) or an outpatient CR led to further improvement of followed parameters in comparison to supervised CR in a hospital (Benzer et al.2007).

Certainly, further research is required, especially in order to optimize the effectiveness of CR programs and to better understand the mechanisms responsible for the improvements related to CR training.

CONCLUSION

In our study, patients with regular 12-month physical activity improved their global left ventricle systolic function mainly due to improvement of contractility in walls supplied by a totally occluded coronary artery.

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2.3. ASSESSING THE LEFT VENTRICLE DIASTOLIC FUNCTION IN A GROUP OF PATIENTS WITH CHRONIC ISCHAEMIC HEART DISEASE AND REGULAR PHYSICAL ACTIVITY

ABSTRACT

Aim: Assessing the left ventricle diastolic function in a group of patients with stable coronary artery disease and regular physical training.

Methods: The study included thirty patients with stable coronary artery disease. Every patient had participated in the conducted 3-month physical training in Department of Functional Diagnostic and Rehabilitation St. Anna Hospital. After one year patients were retrospectively divided into two cohorts according to their physical activity. The patients in cohort C (consists of 14 patients) continued in aerobic physical training after the end of rehabilitation program. The patients in cohort N (consists of 16 patients) had stopped their training after finishing the conducted program in St. Anna Faculty Hospital.

The peak diastolic velocities of myocardial motion were measured at individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine global LV diastolic function, the four-site mean diastolic velocity was calculated (Ea glob, Ea/Aa glob). Velocities were evaluated at rest and at the maximal load.

According to the blood supply, left ventricular walls were divided into five groups: 0- walls supplied by non-stenotic artery; 1- walls supplied by artery with coronary stenosis ≤ 50%; 2- walls supplied by artery with stenosis 51-70%; 3- walls with stenosis of supplying artery 71-99%; 4- walls with totally occluded supplying artery. For every patient the difference between values Ea, Ea/Aa for each wall at the end of the study and the values at the beginning of the study was assessed. The values of particular walls were divided into 5 groups according to the blood supply (this 5 groups were create using coronarography).

The differences of these values at rest and stress between both cohorts of patients were statistically processed using unpaired t-test, the $p<0.05$ was considered statistically significant.

Results: In global diastolic function, the values of Ea global in cohort C were improved by 0.05±2.94 cm/s at rest, and by o 1.27±3.75 cm/s at maximal load, while the values of Ea global in cohort N were diminished by -0.89±2.01 cm/s ($p<0.05$ versus cohort C), and by -0.13±3.20 cm/s; ($p<0.05$ versus cohort C) at maximal load.

The most important benefit at diastolic function was found in group 4 (groups with totally occluded coronary artery). The values of Ea in cohort C were improved by 4.24±3.65 cm/s, while the values in cohort N were diminished by -0.68±2.74 cm/s; ($p<0.05$ versus cohort C) at maximal load. The other Ea values results were not significant.

The Ea/Aa values in group 4 in cohort C were improved by 0.29±0.39 cm/s at maximal load , while values of Ea/Aa in cohort N were diminished by -0.03±0,24 cm/s; ($p<0.05$ versus cohort C) at maximal load. The other Ea/Aa values results were not significant.

Conclusion: Our patients with 12 months training improved their global diastolic function. The most important benefit was found in walls supplied by occluded artery.

Key words: aerobic training, left ventricle diastolic function, chronic ischemic heart disease

INTRODUCTION

The effects of regular physical activity on cardiovascular system and myocardial function are global. The risk factors are reduced (by changing the way of life, strength of thews). Heart rate and blood pressure are decreased, peripheral venous tonus is improved and positive influence on the left ventricle (LV) is probable.

Tissue Doppler imaging (TDI) is echocardiographic method using the Doppler effect. By this method it is possible to measure the velocity of myocardial motion in both systolic and diastolic phases of cardiac cycle [1]. The difference between classic Doppler sonography and TDI is in using special filters, that eliminate signals which are repulsed back by blood cells, and reversible intensify signals that are repulsed by myocardium (these signals are marked with high amplitude and low frequency).

There are two types of TDI: pulsed TDI and colour TDI. Using the pulsed TDI we get the characteristic curve, which consists of three main waves. The positive Sa wave represents a systolic phase of cardiac cycle. This wave is frequently two-phased with the first slim peak of isovolumic contraction (Sa´) and second wider wave of ejection of LV. The first negative wave after the Sa wave is called Ea, it represents fast filling of the ventricle in diastolic phase of cardiac cycle. The second negative wave (Aa) grows from atrium contraction at the end of the diastolic phase of cardiac cycle. The Aa wave is missing in the case of atrial fibrillation [2]. During exercise tests the waves Ea and Aa are often fusing [3] cause to the faster heart rate.

By measuring the amplitude of these single waves, the maximal velocity of each myocardial segment during cardiac cycle can be evaluated. In myocardial pathologies velocity values for each segment and also the overall value of ventricle function are being changed. The velocity of all 17 myocardial segments can be measured [4]. Physiologically, the velocities are getting higher in segments from apex towards heart base. TDI can be used for evaluation of regional and also global function of both ventricles (both systolic and diastolic ventricle function). We can prove the myocardial ischaemia, and the reversible and non-reversible myocardial dysfunction [2]. During ischaemia the maximal Sa and Ea velocities are reduced. The change of Aa is not significant, so the Ea/Aa ratio in ischaemic area is getting down [1].

The purpose of this study was to assess the effect of aerobic training on the left ventricular diastolic function in group of patients with chronic ischemic heart disease.

MATERIALS AND METHODS

The study included thirty patients with stable coronary artery disease. These patients were retrospectively divided into two cohorts with difference in regular physical training. The cohort C consists of 14 patients. These patients had participated in the conducted 3-month physical training in Department of Functional Diagnostic and Rehabilitation St. Anne´s Faculty Hospital, and after the 3-months they had continued with individual training for 9 more months. The regular physical training consists of 3 phase in 60 minutes 3 times a week. The first phase of the training is called warming up and lasts for ten minutes. The second phase is an aerobic period and lasts for 35 minutes. This phase consists of power training and riding a bicycle ergometer. The third phase is a relaxation phase and lasts for 15 minutes. The 9-months individual training consists of regular physical activity performed for one hour at least three times a week. As a regular physical activity the patients should have chosen riding a bicycle-ergometer, cycling, or swimming. The cohort N consists of 16 patients. These patients had stopped the training after finishing the conducted program. Cohort's characteristics are shown in *Table 1*.

Table 1. Study population

	Cohort C	cohort N	
Age (years)	60±10	69±8	*
Number of arteries with stenosis ≥ 70%	1.6±1.1	1.8±1.2	
DM	43%	19%	
MI	50%	63%	
Hypertension	100%	100%	
HLPP	100%	94%	
EF (%)	50.8±10.8	48.6±12.4	
Male/female	13/1	9/7	*

Values are shown as average ± standard deviation;

EF-ejection fraction LV; MI-myocardial infarction; DM-diabetes mellitus; HLPP-hyperlipoproteinemia; * $p<0.05$ between cohorts

At the beginning of the study the coronary angiography was performed. According to the blood supply, left ventricular walls were divided into five groups: 0- walls supplied by nonstenotic artery; 1- walls supplied by artery with coronary stenosis ≤ 50%; 2- walls supplied by artery with stenosis 51-70%; 3- walls with stenosis of supplying artery 71-99%; 4- walls with totally occluded supplying artery.

Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training program and one year later. Three days before the rest/stress dobutamine echocardiography the beta blockers were discontinued. Using commercially available equipment Sonos 5500 (Hewlet-Pacard, US) with transducer 2.5 MHz, echocardiography was performed in standard views – parasternal long axis, parasternal short axis (level of papillary muscles), apical 4- and 2- chamber views. The peak diastolic velocities of myocardial motion were measured at individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine global LV diastolic function, the four-site average diastolic velocity was calculated (Ea glob, Ea/Aa glob). Velocities were evaluated at rest and at the maximal load.

For every patient the difference between values Ea, Ea/Aa for each wall at the end of the study and the values at the beginning of the study was assessed. The values of particular walls were divided into 5 groups according to the blood supply (this 5 groups were create using coronary angiography). The differences of these values during rest and maximal stress between both cohorts of patients were statistically processed using unpaired t-test, a $p<0.05$ was considered statistically significant.

RESULTS

The results are shown in *Table 2*.

In global diastolic function, the values of Ea global in cohort C were improved by 0.05±2.94 cm/s at rest, and by o 1.27±3.75 cm/s at maximal load, while the values of Ea global in cohort N were diminished by -0.89±2.01 cm/s ($p<0.05$ versus cohort C), and by -0.13±3.20 cm/s; ($p<0.05$ versus cohort C) at maximal load.

The most important benefit to the diastolic function was found in group 4 (groups with totally occluded coronary artery). The values of Ea in cohort C were improved by

4.24±3.65 cm/s, while the values in cohort N were diminished by -0.68±2.74 cm/s; (p<0.05 versus cohort C) at maximal load.

Table 2. Changes of value characteristics of diastolic function

	rest						stress					
	Ea			Ea/Aa			Ea			Ea/Aa		
Cohort	C	N		C	N		C	N		C	N	
0	−0.64±2.08	−1.44±1.66		−0.02±0.14	−0.10±0.24		−0.44±2.53	−1.03±2,24		−0.14±0.25	0.04±0.27	
1	0.27±2.93	−0.26±1.37		−0.05±0.28	0.03±0.12		1.25±2.78	2.05±3.37		0.01±0,17	0.11±0.20	
2	0.59±2.62	−1.64±3.69		0.13±0.08	−0.11±0.38		0.51±2.87	0.62±4.97		0.00±0.20	0.13±0.43	
3	0.55±3.68	−0.66±1.71		0.03±0.34	0.14±0.30		−0.04±4.86	−0.48±3.00		0.09±0.57	0.25±0.57	
4	−0.48±2.77	−0.77±2.28		−0.06±0.22	0.03±0.18		**4.24±3.65**	**−0.68±2.74**	*	**0.29±0.39**	**−0.03±0.24**	*
Global function	**0.05±2.94**	**−0.89±2.01**	*	−0.02±0.26	0.02±0.26		**1.27±3.75**	**−0.13±3.20**	*	0.06±0.36	0.09±0.38	

Values are shown as average ± standard deviation;* p<0.05 between cohorts; rest=investigation in rest; stress= investigation during maximal load; C= cohort C; N= cohort N; group 0,1,2,3,4= according to the blood supply; global function= Ea global or Ea/Aa global as a average of all walls LV

The results of the Ea values from other walls were not significant.

The Ea/Aa values in group 4 in cohort C were improved by 0.29±0.39 cm/s at maximal load, while values of Ea/Aa in cohort N were diminished by -0.03±0.24 cm/s; (p<0.05 versus cohort C) at maximal load. The changes of other Ea/Aa values results were not significant.

In cohort C, as the stress test was performed, 12 of 14 patients have stress-induced kinetic disorder, 2 patients have negative stress test. In cohort N, 12 of 16 patients have stress-induced kinetic disorder (4 patients have negative stress test, but 2 of them have typical stress performed chest pain without objective kinetic disorder).

DISCUSSION

In our study, using TDI for assessing changes of the diastolic function of LV, the regular physical activity has positive influence on diastolic function of LV. We found the improvement of global diastolic function during the rest and also during the maximal load. The most important benefit was found in walls supplied by occluded artery.

In the literature, there are very few studies using pulsed TDI to evaluate the effect of cardiac rehabilitation on LV function. Moreover, population cohorts are very different. Schuster et al. [5] reported improvement of global diastolic function assessed by TDI in obese men with subclinical cardiac dysfunction after eight weeks of training. In the cohort of patients with chronic kidney disease, Howden et al. [6] found an improvement of diastolic LV function after comprehensive intervention including physical training. Arbab-Zadeh et al [7] has found that prolonged, endurance training preserves ventricular compliance with aging and may help to prevent heart failure in elderly. In patients with coronary artery disease after myocardial infarction, Deljanin - Ilic et al. [8] has reported that continuous physical training induced significant improvement of regional diastolic LV function. In the study of Yu [9], cardiac rehabilitation and prevention program prevented the progression of resting LV diastolic dysfunction, without affecting systolic function. The improvement of diastolic function predicted the gain in exercise capacity.

However, the results of some studies are different. In the study of Nottin et al [10], master athletes with long-term endurance training were compared with sedentary seniors and young adult men. The authors concluded that the endurance training does not prevent the LV diastolic dysfunction. In post myocardial infarction patients, an 8-week cardiac rehabilitation program led to improved exercise capacity. However, it failed to enhance diastolic function [11]. A 4.5-month training program in post-myocardial infarction patients with preserved systolic function and mild diastolic dysfunction did not led to improve diastolic function in the study of Korzeniowska-Kubacka et al. [12].

We have to be cautious in our conclusion of diastolic function improvement, because the age average in both cohorts is not the same. It is known that the diastolic function is getting worse over the age [13], and the patients in cohort N were significantly older than those in cohort C. And there was also a difference between substitution of men and women in both cohorts [14].

Although our study cannot elucidate the possible mechanism of regional functional improvement, we speculate, that combination of autonomic system changes and especially the development of collaterals may have facilitated partial functional recovery of dysfunctional but viable myocardial regions supplied by a totally occluded coronary artery. Several studies have shown that exercise training programs augment coronary collateral supply to native vessels. There appears to be a dose-response relation between coronary collateral flow augmentation and exercise capacity gained [15].

Our study has several limitations. The interpretations of results may be limited by a relatively small number of patients in both cohorts. Also, our study can be influenced by the difference between the number of men and women and the difference between patients´ age in both cohorts.

CONCLUSION

In our study, patients with regular 12-month physical activity improved their global left ventricle diastolic function mainly due to improvement of regional diastolic function in walls supplied by a totally occluded coronary artery.

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2.4. THE PROGNOSTIC EFFECT OF DIFFERENT TYPES OF CARDIAC REHABILITATION IN PATIENTS WITH CORONARY ARTERY DISEASE

ABSTRACT

Aim: The purpose of this study was to access and compare the prognostic effects of different types of cardiac rehabilitation (CR) in patients with chronic coronary artery disease.

Methods: One hundred fifty two patients were retrospectively divided into 4 groups according to their adherence to physical activity recommendations. Patients in groups 1 and 2 participated in the guided 3-month exercise program. Patients in group 1 then continued with individual exercise training, while patients in the group 2 stopped exercising after finishing the guide exercise program. Patients in group 3 participated only in individual exercise training throughout the whole follow-up period, and patients in group 4 declined all exercise recommendations and did not exercise. The prognostic outcome of different types of cardiac rehabilitation was compared among groups. In addition, patients who participated in individual exercise training according to recommendations (cohort IT+) were compared with patients who declined these activities (cohort IT-).

Results: During a median follow-up of 94 months, 33 deaths occurred: 17 cardiovascular and 16 non-cardiac deaths. A Kaplan-Meier survival analysis demonstrated significantly better survival rates for patients who followed a long-term aerobic exercise training (IT+) than for those who did not participate or who had only a short-term exercise programs (IT-) ($p=0.009$).

Conclusion: In our study, long-term exercise training had a higher impact on patient survival than short-term guided CR.

Key words: coronary artery disease, cardiac rehabilitation, prognosis, cardiovascular risk

INTRODUCTION

The beneficial effects of cardiac rehabilitation (CR) on secondary prevention of coronary artery disease are well-established and regular physical activity, including exercise, is recommended by many guidelines [1-3]. The major objective benefits are an increased exercise capacity [4] and reduced rates of cardiac events and mortality [5]. In addition, the beneficial effects on cardiovascular risk factors – blood pressure, lipid levels, glucose metabolism, body weight, as well as on the endothelial function and psychological well-being – have also been proven [6].

The structure and intensity of CR programs varies widely among different countries and centers [7]. However, in spite of their benefits and guideline recommendations, only a minority of eligible patients participated in and completed these programs. Alternative home-based CR activities might help to solve the problems of the poor uptake and adherence of outpatients or inpatients to center-based CR programs. Furthermore, the physical activity behaviors of patients, especially their participation in walking and vigorous activities, were found to be inversely associated with the use of antidiabetic, antihypertensive, and lipid-lowering drugs [8, 9].

The purpose of this study was to assess and compare the prognostic effects of different types of aerobic exercise programs in patients with chronic stable coronary artery disease.

PATIENTS AND METHODS

Patient population and study protocol

The study comprised 152 consecutive patients with stable coronary artery disease with at least one coronary artery stenosis more than 50% in luminal diameter (proved by the coronary angiography performed before the study). The exclusion criteria were: 1. coronary artery bypass graft or coronary intervention less than 3 months before inclusion; 2. known need for future coronary revascularization; 3. unstable patients; 4. hemodynamically important valve disease; 5. non-cardiac disease adversely affecting prognosis; and 6. non-cardiac disease seriously limiting the participation in cardiac exercise programs.

Participation in the supervised outpatient cardiac rehabilitation and individual aerobic exercise training programs were recommended to all patients. After the follow-up, the patients were retrospectively divided into 4 groups according to their acceptance of the exercise recommendation. Patients in groups 1 and 2 participated in the guided 3-month physical exercise program. Patients in group 1 continued to exercise individually; patients in the group 2 stopped their exercise after finishing the guided program. Patients in group 3 participated only in an individual exercise training program throughout the follow-up period, and patients in group 4 declined all exercise recommendations and did not exercise. For further evaluation of the effect of different types of aerobic exercise, patients who attended the supervised cardiac rehabilitation (cohort CR+, comprising patients of groups 1 and 2) were compared with patients who did not (cohort CR-, comprising patients of groups 3 and 4). Similarly, patients who participated in individual training program in accordance with the recommendation (cohort IT+, comprising patients of groups 1 and 3) were compared with patients who declined these activities (cohort IT-, comprising patients of groups 2 and 4).

During follow-up period, all patients were medically treated according to the evidence-based medicine. Significant effort was spent also on motivating the patients toward nonpharmacological treatment of risk factors, including not only physical exercise, but also smoking cessation, dietary and weight recommendations. Mortality and major adverse cardiac events (MACE) were assessed during follow-up visits. The primary end-point was all-cause mortality; the secondary end-points were a composite of MACE, including myocardial infarction, unstable angina pectoris, coronary revascularization, and hospitalization for heart failure.

The study was in accordance with the Declaration of Helsinki (2000) of the World Medical Association, and was approved by the institutional ethics committee. Written consent was obtained from each patient.

Physical exercise

The guided program offered 3 months of 3 times weekly sessions. Each session lasted for 60 minutes and consisted of 3 different phases: 10 minutes of warm-up, 20 minutes of aerobic exercise on a bicycle ergometer with a load intensity at the level of anaerobic threshold, 20 minutes of resistance training on combined training machine, and 10 minutes of relaxation.

Aerobic exercise intensity was individually prescribed according to initially performed symptom-limited spiroergometry. The protocol with intensified workload up to the symptom- limited maximum was used starting on 40W, increasing by 20W each 2 minutes. The respiratory gases were analyzed under physical exercise (Blood Gas Analyser, MedGraphics, USA). The anaerobic threshold value for prescribing suitable load intensity was determined according to the corresponding value of heart rate and degrees of the Borg scale of subjective perception of load intensity.

The individual exercise training program consisted of regular physical activity performed for a minimum of 1 hour at least 3 times per week. As a regular physical activity, patients were asked to choose cycling, riding a veloergometer or swimming.

Statistical analysis

For descriptive purposes, basic summary statistics such as mean, median, standard deviation, minimum and maximum were assessed for continuous data analysis, and absolute and relative frequencies for binary and categorical data. Groups were compared in continuous parameters by ANOVA or Kruskal-Wallis ANOVA test if appropriate (the Kolmogorov-Smirnov test was used to analyze distribution of data). Distribution of binary and categorical data between groups was tested by a chi-square test.

Survival analysis (overall survival and cardiovascular survival) was performed using the Kaplan-Meier method, and groups were compared by log-rank test or by chi-square test. Cox proportional hazard regression model was used for multivariate analysis. All data were analyzed at the significance level of a=0.05, and all the tests were two-tailed.

RESULTS

Baseline patient characteristics are presented in Tables 1 and 2. Most parameters were similar in all four groups, but there were significant differences among the groups in age, sex, and in the number of diabetic and dyslipidemic patients. Medical treatment before the study and after follow-up is shown in Tables 3 and 4. No statistically significant differences were found among the 4 groups.

During a median follow-up of 94 months (range 2-158) after inclusion, there were 33 deaths (17 cardiovascular and 16 non-cardiac deaths). The Kaplan-Meier survival curve for all four groups is shown in Figure 1. Patients in group 3 had statistically better survival than group 2 (p=0.042) and group 4 (p=0.041). The survival between other groups did not differ statistically. The result of an overall test comparing all patient groups bordered on statistical significance (p=0.067). No significant differences in survival were found between cohorts CR+ and CR- (p=0.948). However, patients in cohort IT+ had longer survival rates than cohort IT- (p=0.009) (Figure 2). Multivariate Cox regression analysis including baseline covariates (sex, age, diabetes mellitus, and dyslipidemia) revealed group as an independent factor for survival on the borderline of statistical significance (p=0.057).

The secondary end-points are shown in Table 5. The incidence of each of unstable angina pectoris, coronary revascularization, and hospitalization for heart failure significantly differs among the groups and was higher in cohort IT- than cohort IT+. The composite secondary end-point differed significantly among groups and between cohorts IT+ and IT-, but no difference was found between cohorts CR+ and CR-.

Table 1. Study groups characteristics: medical history (groups 1-4)

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
Age (years)	71.5 ± 10.0	71.8 ± 8.8	63.8 ± 10.3	73.9 ± 8.7	0.002*
Men	32 (100.0%)	43 (71.7%)	20 (90.9%)	27 (71.0%)	< 0.001*
BMI	27.3 ± 3.3	28.3 ± 3.0	28.3 ± 3.0	27.6 ± 3.8	0.622
LVEF (%)	48.6 ± 8.8	46.9 ± 10.1	49.5 ± 7.6	50.1 ± 11.6	0.276
No of stenotic arteries (≥ 70%)	1.5 ± 0.7	1.5 ± 0.7	1.4 ± 0.6	1.4 ± 0.6	0.526
Coronary revascularization	19 (59.4%)	29 (48.3%)	15 (68.2%)	17 (44.7%)	0.243
DM	5 (15.6%)	19 (31.7%)	2 (9.1%)	14 (36.8%)	0.028*
Hypertension	31 (96.9%)	58 (96.7%)	22 (100.0%)	37 (97.4%)	0.727
Dyslipidaemia	25 (78.1%)	53 (88.3%)	22 (100.0%)	38 (100.0%)	< 0.001*
Smoking	8 (25.0%)	8 (13.3%)	7 (31.8%)	6 (15.8%)	0.223

Values are expressed as the mean ± standard deviation or the number of subjects with the percentage in parentheses.

BMI = body mass index; LV EF = left ventricular ejection fraction; DM = diabetes mellitus; * $p < 0.05$ between groups.

Table 2. Study cohort characteristics: medical history (groups CR+, CR-, IT+, IT-)

Parameter	Group CR+ (n = 92)	Group CR– (n = 60)	*P* value	Group IT+ (n = 54)	Group IT– (n = 98)	*P* value
Age (years)	71.7 ± 9.1	70.2 ± 10.4	0.392	68.4 ± 10.7	72.6 ± 8.7	0.007*
Men	75 (81.5%)	47 (78.3%)	0.679	52 (96.3%)	70 (71.4%)	< 0.001*
BMI	27.9 ± 3.2	27.9 ± 3.5	0.867	27.7 ± 3.2	28.0 ± 3.3	0.585
LVEF (%)	47.5 ± 9.7	49.9 ± 10.2	0.091	48.9 ± 8.3	48.1 ± 10.8	0.519
No of stenotic arteries (≥ 70%)	1.5 ± 0.7	1.4 ± 0.6	0.148	1.4 ± 0.7	1.5 ± 0.7	0.868
Coronary revascularization	48 (52.2%)	32 (53.3%)	0.999	34 (63.0%)	46 (47.0%)	0.064
DM	24 (26.1%)	16 (26.7%)	0.999	7 (13.0%)	33 (33.7%)	0.007*
Hypertension	89 (96.7%)	59 (98.3%)	0.999	53 (98.1%)	95 (96.9%)	0.999
Dyslipidaemia	78 (84.8%)	60 (100.0%)	< 0.001*	47 (87.0%)	91 (92.6%)	0.253
Smoking	16 (17.4%)	13 (21.7%)	0.532	15 (27.8%)	14 (14.3%)	0.053

Values are expressed as the mean ± standard deviation or the number of subjects with the percentage in parentheses.

CR+ = patients who participated in the guided exercise program (comprising patients of groups 1 and 2); CR- = patients who declined to participate in the guided exercise program (comprising patients of groups 3 and 4); IT+ = patients who exercised individually training (comprising patients of groups 1 and 3); IT- = patients who declined individual exercise (comprising patients of groups 2 and 4); BMI = body mass index; LV EF = left ventricular ejection fraction; DM = diabetes mellitus; * $p < 0.05$ between cohorts

Table 3. Study population characteristics: medical treatment before the study

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
ASA	31 (96.9%)	57 (95.0%)	20 (90.9%)	35 (92.1%)	0.748
Beta-blockers	29 (90.6%)	58 (96.7%)	22 (100.0%)	35 (92.1%)	0.236
ACEI	28 (87.5%)	50 (83.3%)	21 (95.5%)	28 (73.7%)	0.123
Sartans	0 (0.0%)	1 (1.7%)	1 (4.6%)	0 (0.0%)	0.393
Statins	23 (71.9%)	49 (81.7%)	19 (86.4%)	35 (92.1%)	0.146
Nitrates	24 (75.0%)	41 (68.3%)	13 (59.1%)	29 (76.3%)	0.495

Values are expressed as the number of subjects with the percentage in parentheses.

ASA = acetylsalicylic acid; ACEI = angiotensin-converting-enzyme inhibitor

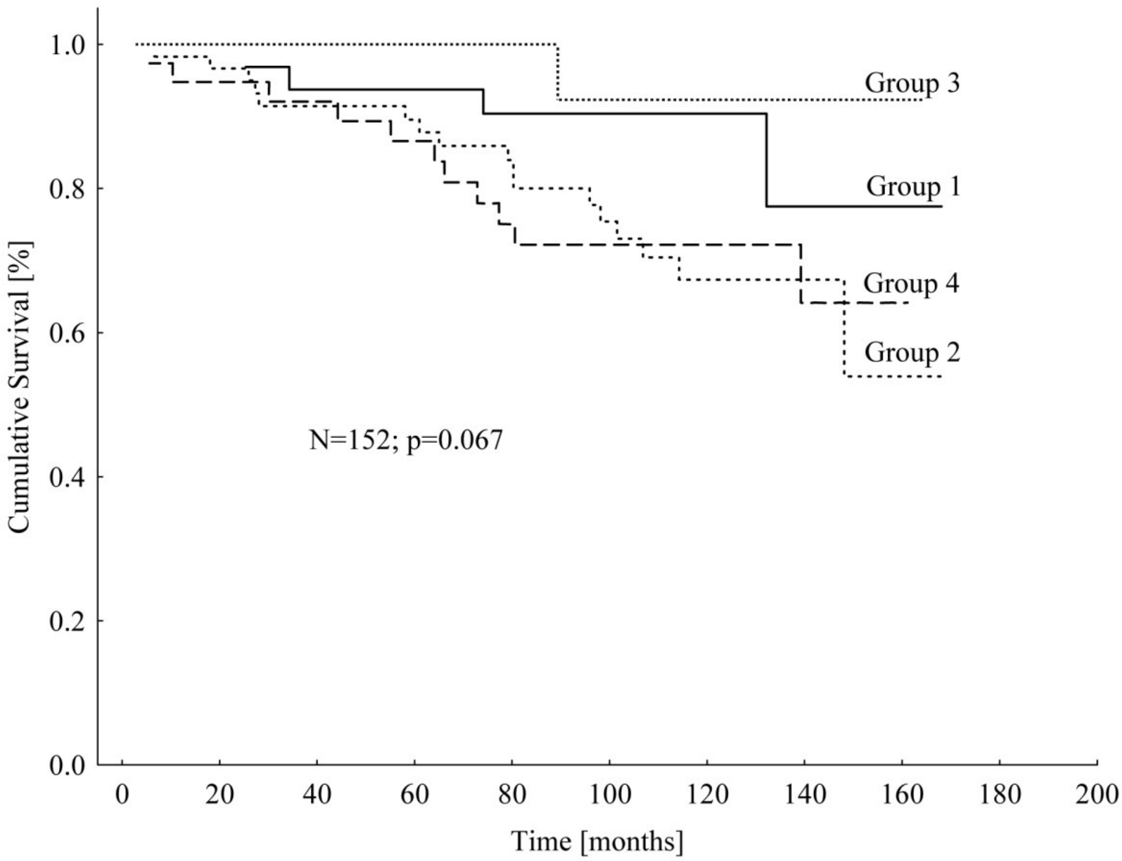
Table 4. Study population characteristics: medical treatment at the end of the follow up

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
ASA	31 (96.9%)	58 (96.7%)	20 (90.9%)	36 (94.7%)	0.740
Beta-blockers	30 (93.8%)	58 (96.7%)	22 (100.0%)	35 (92.1%)	0.351
ACEI	21 (65.6%)	45 (75.0%)	19 (86.4%)	25 (65.8%)	0.243
Sartans	2 (6.3%)	8 (13.3%)	4 (18.2%)	5 (13.2%)	0.572
Statins	28 (87.5%)	54 (90.0%)	20 (90.9%)	35 (92.1%)	0.935
Nitrates	18 (56.3%)	39 (65.0%)	13 (59.1%)	30 (79.0%)	0.182

Values are expressed as the number of subjects with the percentage in parentheses.

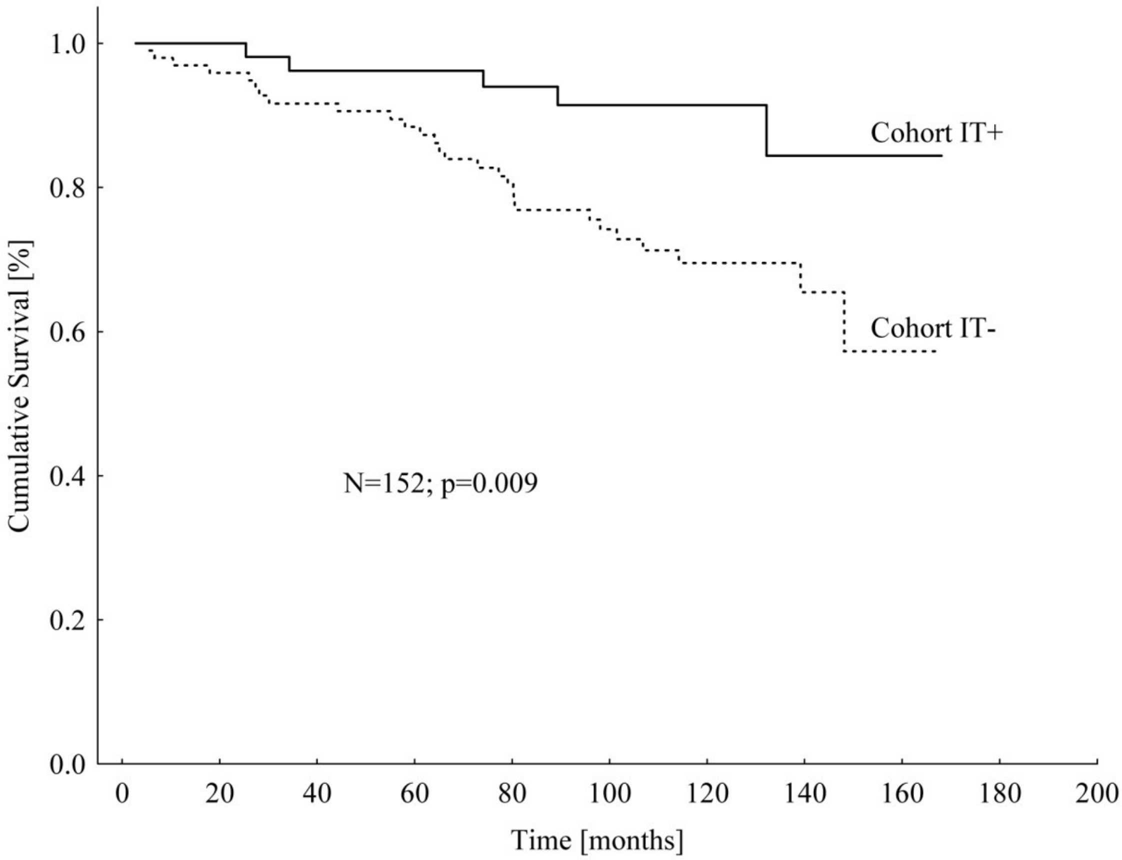
ASA = acetylsalicylic acid; ACEI = angiotensin-converting-enzyme inhibitors.

Figure 1. Kaplan-Meier curve for patient survival according to the physical activity – a comparison of 4 groups of patients



Group 1 = patients participated in the supervised 3-month physical exercise program and continued to exercise individually; Group 2 = patients participated in the supervised 3-month physical training and stopped exercise after that; Group 3 = patients only exercised individually throughout the whole follow-up period; Group 4 = patients declined all exercise recommendations and did not perform any exercise activities.

Figure 2. Kaplan-Meier curve for patient survival according to the physical activity – a comparison of cohorts IT+ and IT-.



Cohort IT+ = patients who exercised individually; Cohort IT- = patients who declined individual exercise.

Table 5. Secondary end-points in groups and cohorts

	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value		
					Among groups	CR + vs CR–	IT + vs IT–
MI	2 (6%)	5 (8%)	1 (5%)	7 (18%)	0.249	0.275	0.149
UAP	6 (19%)	22 (37%)	1 (5%)	8 (21%)	0.008*	0.034*	0.018*
Revascularization	4 (13%)	22 (37%)	3 (14%)	13 (34%)	0.020*	0.855	0.002*
HF	0 (0%)	10 (17%)	1 (5%)	4 (11%)	0.017*	0.783	0.020*
MI + UAP + revascularization + HF	8 (25%)	36 (60%)	4 (18%)	21 (55%)	< 0.001*	0.368	< 0.001*

Values are expressed as the number of subjects with the percentage in parentheses.

CR+ = patients who participated in the guided exercise program (comprising patients of groups 1 and 2); CR- = patients who declined to participate in the supervised training (comprising patients of groups 3 and 4); IT+ = patients who exercised individually (comprising patients of groups 1 and 3); IT- = patients who declined individual exercise (comprising patients of groups 2 and 4); MI = myocardial infarction; UAP = unstable angina pectoris; HF = hospitalization for heart failure; * $p< 0.05$ among groups or between cohorts.

DISCUSSION

The present study showed that an individual, long-term exercise program has a higher impact on patient survival and rate of MACE than a short-term hospital-based CR program. The potential beneficial effect of supervised exercise training is probably lost when the increased physical activity does not continue also after the guided program is finished.

Physical activities clearly reduce the mortality of coronary artery disease patients [10]. While this is encouraging, the success of CR is largely dependent on patient adherence to exercise recommendations during both supervised exercise and self- managed exercise programs. Unfortunately, the data show poor attendance and high dropout rates in guided CR. For example, Hansen et al [11] followed 119 patients with coronary artery disease 18 months after inpatient rehabilitation. They found very poor adherence (27%) to the recommended minimal physical activity level during the follow-up, low habitual physical activity in the total group, and progressively worsened cardiovascular disease risk profile of the patients. Similarly, Reid et al [12] found a significant decrease in habitual physical activity during long-term follow-up after hospital discharge in patients with coronary artery disease. The PIN study [13] showed that the benefit of CR therapy following myocardial infarction or coronary revascularization is only partially maintained during the following year. The cardiac risk factors improved initially during CR, but deteriorated over the next 12 months.

The beneficial effect of cardiac rehabilitation is nowadays well recognized. However, it remains largely obscure, which characteristics of physical activity and exercise training are the most effective. In general, recommendations of exercise training programmes need to be tailored to the individual's exercise capacity and risk profile, with the aim to reach and maintain the individually highest fitness level possible[14]. A center-based CR has several advantages, including better exercise supervision with possibilities for correcting the intensity and type of exercise as well as addressing safety issues. On the other hand, supervised CR could be more difficult for some patients to attend. Older age and high co-morbidity are strong predictors for non-attendance [15]. A valid alternative is home-based CR. These programs are as effective as center-based CR, but seem hopeful in targeting higher number of patients [16-20]. Our study confirmed that long-term individual CR is a very good alterative and could be even more effective than short-time guided exercise program.

In several studies, such as the HF-ACTION study [21, 22], exercise led only to a non-significant reduction in all-cause mortality or hospitalization. These studies failed to meet the previous expectations most probably due to non-uniform adherence to scheduled physical activity levels and a high percentage of exercise cross-over from training group. In the HF-ACTION study, only approximately 40% of the patients in the exercise group reported weekly exercise volumes at or above the recommended level. Reasons for non-attendance usually varied- patients being "uninterested", illness, work scheduling, and transportation issues [23]. Patients are not easily convinced to permanently change their lifestyle habits. From the results of our study, it can be deduced that the initial patient enthusiasm for physical exercise and lifestyle changes and their resulting compliance with the exercise recommendations are the most important factors which influencing the effect of exercise programs.

The results of the present study are certainly influenced by the fact that it is non-randomized study and patients were divided into groups retrospectively according to their acceptance of the exercise recommendations. Patient motivation and willingness to exercise played an important role in the study, and most probably also in their lifestyle behavior. Other potential prognostic factors, such as dietary behavior, weight maintenance or loss, and medication compliance, were not assessed in this study. Nevertheless, all patients were treated according to the evidence-based medicine, and a significant effort was spent on motivating the patients toward nonpharmacological treatment of risk factors, including not only physical exercise, but also dietary and weight recommendations and smoking cessation.

The interpretations of results could be limited by the relatively small sample size of the groups. The study could also be influenced by the differences in age, gender, and diabetic and dyslipidemic patients among the groups. Younger men showed the best compliance to individual aerobic exercise, and this certainly may have influenced the results of our study. However, multivariate Cox regression analysis including baseline covariates (sex, age, diabetes mellitus, and dyslipidaemia - where significant differences were found among groups) revealed group as an independent factor for survival on the borderline of statistical significance.

In this study, no other outcomes than mortality and mortality was assessed. It has been reported previously that the change in aerobic capacity after CR was related to mortality. Accorging to the study of Vanhees et al, a 1% greater increase in peak oxygen uptake (VO_2) after training was associated with a decrease in cardiovascular mortality of 2%. Peak VO2, evaluated after a physical training program, and its change in response to training were independent predictors for cardiovascular mortality in patients with coronary artery disease [24]. Physical training generally increases exercise capacity. The effect of our conducted 3 month training on functional capacity improvement is known and was published previously by our group [25]. However, patients in our trial had no aerobic capacity evaluation at the end of the follow-up. So that no direct comparison of the impact different training programmes on aerobic capacity is possible.

Another limitation is the fact, that the outpatient individual exercise was performed without any supervision. The information about frequency and intensity was obtained only from patient anamnesis during regular visits to the outpatient department. And finally, the cut off of individual exercise training at minimum duration of 1 hour at least 3 times per week was defined for the group categorization. However, very different types of exercise programs are described in the literature and in some studies a home-based CR had no significant differences from a guided center-based CR programs in the main outcomes [18], or an outpatient CR led to further improvements than an in-hospital supervised CR [7]. Certainly, further research is required, especially in order to optimize the effectiveness of CR programs and to better understand the mechanisms responsible for the improvements related to CR exercise.

CONCLUSION

In our study, individual long-term exercise program had higher impact on patient survival and rate of MACE than short-term hospital-based guided CR.

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2.5. SOUHRN

V práci byl zkoumán vliv různých druhů tréninku na změnu parametrů zátěžového ergometrického testu, na systolickou a diastolickou funkci LK a na prognózu nemocných s chronickou ICHS. Byl srovnáván především řízený rehabilitační program s individuální pohybovou aktivitou a jejich různé kombinace.

V souboru 64 pacientů nebyly po 1 roce sledování změny hodnocených parametrů ergometrického zátěžového testu dostatečně velké k dosažení statisticky významných rozdílů. Ale i tak bylo možno pozorovat trendy k většímu zlepšení zátěžové kapacity a tolerance, jakožto i zlepšení dalších parametrů u skupin nemocných cvičících intenzivně a trvale doma a to nezávisle na absolvování řízeného rehabilitačního programu. Naopak trend ke zhoršení těchto parametrů byl pozorován u skupin individuálně po dobu sledování necvičících, a to nezávisle na tom, zda absolvovali úvodní 3-měsíční řízený rehabilitační program.

V echokardiografické části studie bylo v souboru 30 nemocných pomocí TDI zjištěno zlepšení celkové systolické funkce LK po 1 roce pouze u té části nemocných, kteří po úvodním 3-měsíčním řízeném tréninku dokázali navázat vlastní tréninkovou aktivitou. Tato studie byla vůbec první, která prováděla i analýzu vlivu tréninku na regionální funkci LK dle povodí věnčitých tepen. V rámci této analýzy bylo zjištěno, že příznivý efekt cvičení byl dán zlepšením regionální kontraktility v povodí uzavřených tepen.

Velmi podobné výsledky byly dosaženy při hodnocení diastolické funkce LK. U 30 nemocných došlo po 1 roce opět ke statisticky významnému zlepšení celkové diastolické funkce pouze u těch nemocných, kteří po řízeném programu trénovali individuálně. I zde byl efekt dán především zlepšení stěn v povodí uzavřených tepen. Je pravděpodobné, že mechanismem zlepšení regionální funkce LK v povodí uzavřené tepny by mohl být pravidelnou tělesnou aktivitou způsobený rozvoj kolaterál. Proto tento předpoklad však naše studie nebyly designovány a tudíž nemohly přinést jeho jednoznačný důkaz.

V prognostické části studie se 152 nemocnými bylo v rámci 94-měsíčního sledování zjištěno, že dlouhodobý individuální trénink zlepšuje přežití nemocných a snižuje množství závažných kardiálních nežádoucích účinků (nestabilní anginy pectoris, nutnosti koronární revaskularizace, hospitalizace pro srdeční selhání). Výsledky se lišily jen na základě dlouhodobě individuální tělesné aktivity. Naproti tomu případný positivní efekt řízeného programu se během času ztratil.

Všechny studie z různých úhlů pohledu a dle rozdílných hodnocených parametrů prokázaly zásadní vliv dlouhodobé tělesné aktivity nemocných s chronickou ICHS. Pouze dlouhodobým pravidelným tréninkem lze dosáhnout zlepšení zátěžové tolerance, zlepšení systolické a diastolické funkce LK a především zlepšení životní prognózy. Práce neměla v úmyslu nikterak zpochybnit důležitost řízených rehabilitačních programů, které mají jistě nesporné výhody, jako je přizpůsobení tělesné aktivity na míru individuálním pacientům, nastartování pohybového režimu u nemocných, kteří ho dosud neměli a potenciálně větší bezpečnost tělesné aktivity u rizikových jedinců. Pokud ale chceme nemocným zlepšit jejich prognózu, nebo alespoň jejich srdeční funkci, je třeba je motivovat k, pokud možno trvalé, změně jejich životního stylu, a to především směrem k pravidelné tělesné aktivitě.

2.6. ZÁVĚR

Rehabilitační program je důležitou složkou léčby nemocných s chronickou ICHS. Dlouhodobá individuální pohybová aktivita přináší nemocným významně větší prospěch než krátkodobý řízený rehabilitační program, a to jak ve smyslu zlepšení systolické a diastolické funkce LK, tak i zlepšení prognózy. Pravidelná aerobní tělesná aktivita by se měla stát trvalou součástí životního stylu nemocných s chronickou ICHS.

2.7. PŘÍLOHY – ORIGINÁLY PUBLIKOVANÝCH PRACÍ

Srovnání řízeného a nekontrolovaného aerobního tréninku nemocných s chronickou ischemickou chorobou srdeční

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Narodil se v roce 1970. Po promoci na LF MU v Brně (1994) nastoupil na I. interní kardioangiologickou kliniku FN U sv. Anny v Brně, kde působí dosud. Zde pracuje především na standardním kardiologickém oddělení, v ambulanci pro konzervativní terapii ischemické chorby srdeční a v echokardiografické laboratoři. Atestaci z vnitřního lékařství I. stupně složil v roce 1997, atestaci z kardiologie v roce 2002. V roce 2003 obhájil doktorandskou disertační práci na téma Perspektivy ultrazvukové charakteristiky tkání v kardiologii (Využití v hodnocení viability myokardu). Je autorem nebo spoluautorem 60 publikací. Mezi hlavní odborné zájmy patří neinvazivní kardiologie, echokardiografie, rehabilitace pacientů s ischemickou chorobou srdeční a buněčná léčba kardiologických pacientů.

Klíčová slova

tělesný trénink – ischemická choroba srdeční – ergometrie

Souhrn

Cíl: Cílem práce bylo srovnat parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční (ICHS) s řízeným a nekontrolovaným aerobním tréninkem. *Soubor a metodologie:* 64 nemocných s chronickou ICHS bylo rozděleno do 4 skupin podle intenzity a druhu aerobního tréninku. Do skupiny A bylo zařazeno 17 pacientů, kteří se zúčastnili řízeného 3měsíčního rehabilitačního programu a navázali na něj individuálním cvičením. Ve skupině B bylo 22 pacientů, kteří absolvovali jen řízený program bez následného individuálního tréninku. Ve skupině C bylo 10 pacientů, kteří neabsolvovali rehabilitační program, ale doma intenzivně cvičili. Do skupiny D bylo zařazeno 15 pacientů, kteří se nezúčastnili rehabilitačního programu, ani doma necvičili. Ergometrické testy byly provedeny před zařazením do studie a po 1 roce sledování. Byly hodnoceny změny těchto parametrů: celkový čas zátěže, celkově vykonaná práce, pracovní kapacita, pracovní tolerance, čas do stenokardií, deprese ST-úseku ve svodu V5 při maximální zátěži. *Výsledky:* Pro nemocné ve skupině C byl zjištěn trend ke zlepšení ve všech hodnocených parametrech s výjimkou prohloubení deprese úseku ST ve svodu V5 při maximální zátěži. Ve skupině A nemocní dosáhli delšího celkového času zátěže, vykonali větší celkovou práci a měli vyšší pracovní toleranci, v ostatních parametrech došlo ke zhoršení. Pacienti ze skupin B a D se zhoršili ve všech parametrech. Všechny rozdíly v jednotlivých skupinách ani mezi skupinami navzájem nebyly statisticky významné. *Závěry:* Parametry opakovaného ergometrického testu nemocných podstupujících jednotlivé typy rehabilitačních programů se od sebe statisticky nelišily. Byl konstatován trend ke zlepšení zátěžových parametrů u skupin nemocných cvičících intenzivně a trvale doma a trend ke zhoršení u skupin individuálně necvičících, a to nezávisle na absolvování úvodního řízeného rehabilitačního programu.

Keywords

physical training – coronary heart disease – ergometry

Summary

Comparison of controlled and uncoltrolled aerobic physical training of patients with chronic coronary heart disease. *Purpose:* The purpose of this study was to compare the effect of the controlled or uncontrolled aerobic physical training in patients with stable coronary artery disease (CAD). *Methogology and group:* 64 patients with stable CAD were divided into 4 groups according to the intensity and form of aerobic training. The group A comprised 17 patients, who had taken part in a conducted training program for 3 months and have continued with individual training. 22 patients (group B) had participated in the training program without follow-up individual exercise. Patients in groups C and D had not taken part in the controlled training program. 10 group C patients had intensively exercised at home (cycling, running, etc.), whereas 15 group D patients had not exercised at all. ECG (electrocardiogram) stress tests on a bicycle ergometer were performed before the training and 1 year later. The changes of following parameters were assessed: the total exercise duration, total work load, exercise capacity, exercise tolerance, the time to onset of angina and ST-segment depressions at the lead V5 in the maximal load. *Results:* Patients in the group C exhibited trends to improve in all parameters, with the exception of ST-segment depression at the lead V5 in the maximal exercise load. Patients in the group A exhibited trends to reach longer exercise duration, higher total work load and higher exercise capacity comparing with the basal stress test. Patients in the group B and D exhibited trends to worsen all parameters. Differences in groups and between groups were not statistically significant. *Conclusion:* In patients with stable CAD and different types of aerobic physical training, exercise parameters did not statistically differ. The trend toward improving stress parameters was identified only in patients, who had intensively exercised at home, independently of participating in the conducted training program.

Úvod

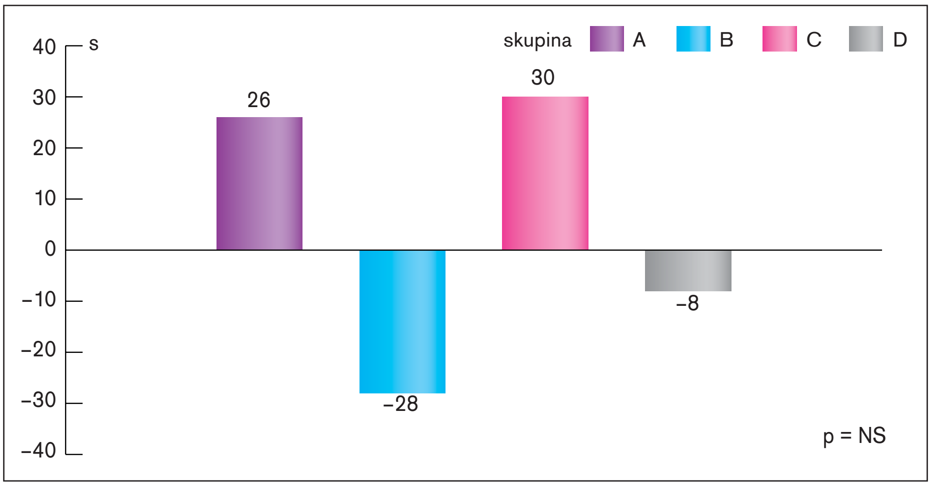
Příznivý vliv fyzické aktivity na kardiovaskulární systém je nesporný nejen u zdravých jedinců, ale i u nemocných s kardiovaskulární chorobami. Pravidelná aerobní zátěž nemocných se srdečními chorobami zlepšuje kvalitu života, omezuje jejich symptomy a snižuje mortalitu [1–8]. Děje se tak příznivým ovlivněním rizikových faktorů vzniku a progrese především ischemické choroby srdeční. Dochází k ovlivnění lipidového metabolizmu snížením LDL- a zvýšením HDL-cholesterolu [5,9–10]. Zvyšuje se také senzitivita k inzulinu a spolu s dietními opatřeními dochází k redukci obezity [5,11]. Dochází ke snížení klidové sympatikoadrenální aktivity, což spolu s omezením agregace krevních destiček a poklesem plazmatických hladin fibrinogenu vede ke snížení rizika vzniku akutního koronárního syndromu.

U nemocných s ischemickou chorobou srdeční má pravidelné cvičení řadu příznivých účinků vedoucích ke zmírnění anginózních potíží i objektivních známek ischemie myokardu při zátěžových testech – zvýšení tolerance zátěže, snížení depresí ST-úseku atd. Tyto změny jsou způsobeny několika mechanizmy – pravidelný trénink způsobuje jednak snížení srdeční práce tím, že se sníží spotřeba kyslíku (snížením tepové frekvence a krevního tlaku) [4,12–16] a zároveň má vliv i na zlepšení přísunu kyslíku (rozšířením epikardiálních koronárních arterií, zvýšením denzity myokardiálních kapilár a rozvojem kolaterál) [17–18]. Při dostatečně intenzivní zátěži (spolu s redukcí ostatních rizikových faktorů) může dojít k zastavení progrese, příp. i k mírné regresi angiografických změn na koronárních arteriích [4,13,19–20].

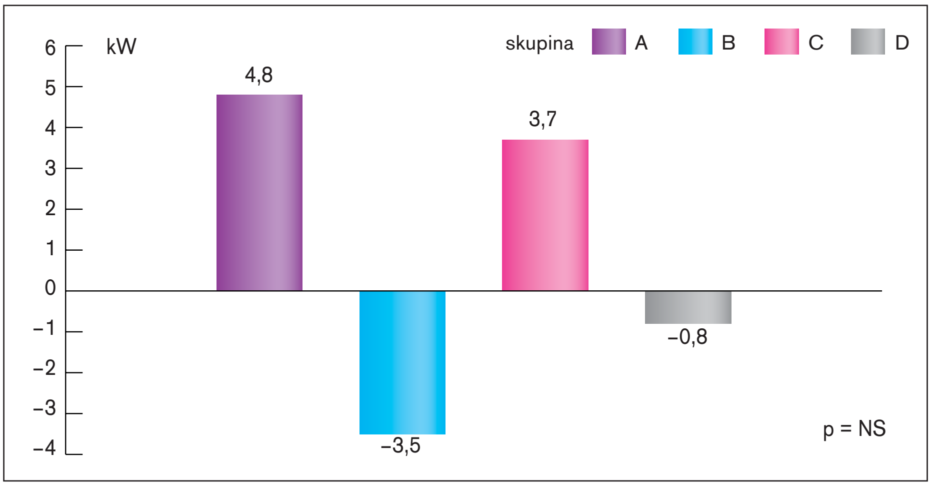
Hledají se optimální druhy a režimy tréninku (např. aerobní trénink s posilováním nebo bez něj), různé frekvence a délky cvičení. Prakticky všechny práce hodnotící nejrůznější řízené tréninkové programy přinášejí důkazy o jejich příznivých efektech. Existuje ale i dostatek prací, popisujících zlepšení stavu pacientů, kteří se o svůj pohybový režim starají více či méně sami. Dosud chybí studie srovnávající řízené a individuální nekontrolované aerobní cvičení. Proto bylo cílem této práce srovnat parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční s řízeným a nekontrolovaným aerobním tréninkem.

Materiál a metodologie

Do studie bylo zařazeno 64 nemocných s chronickou ischemickou chorobou, kteří splňovali následující kritéria: onemocnění koronárních tepen bylo ověřeno koronarografií (zúžení průměru lumina tepny > 50 % na alespoň jedné hlavní koronární tepně); bez anamnézy prodělané ataky nestabilní anginy pectoris nebo infarktu myokardu v posledních 3 měsících před zařazením do studie; bez anamnézy revaskularizace myokardu koronární angioplastikou nebo aortokoronárním bypassem v posledních 3 měsících před zařazením do studie; nepřítomnost významné chlopenní vady a destabilizované hypertenze. Všem nemocným byl opakovaně a důkladně vysvětlen příznivý účinek tělesné aerobní aktivity na jejich zdravotní stav, byla jim doporučena pravidelná aerobní aktivita a nabídnut 3měsíční řízený rehabilitační program. Všichni nemocní podstoupili ergometrický zátěžový test při zařazení do studie a po 1 roce sledování.



Graf 1. Srovnání změn celkového času zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.



Graf 2. Srovnání změn celkové práce během zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.

Tab. 1. Charakteristiky pacientů.

skupina	počet	věk (roky)	nadváha (%)	HT (%)	DM (%)	DLP (%)	AP	IM (%)	počet tepen	CABG (%)	PTCA (%)	EF (%)
A	17	66	71	65	24	82	1,2	53	2,3	18	41	48
B	22	66	82	45	23	82	1,3	86	1,6	14	41	45
C	10	60	80	70	20	90	1,3	90	1,9	20	70	43
D	15	63	67	73	20	73	1,4	60	2,2	20	27	49

HT = hypertenze, DM = diabetes mellitus, DLP = dyslipoproteinemie, AP = stupeň anginy pectoris podle kanadské klasifikace (CCS), IM = počet nemocných po infarktu myokardu, počet tepen = průměrný počet tepen postižených významnou stenozou, CABG = počet nemocných po aortokoronárním bypassu, PTCA = počet nemocných po perkutánní koronární angioplastice, EF = ejekční frakce levé komory.

Zpětně byly nemocní rozděleni do 4 skupin podle intenzity a druhu jejich aerobního tréninku. Do skupiny A bylo zařazeno 17 pacientů (14 mužů a 3 ženy, průměrný věk 66 ± 11 let), kteří se zúčastnili řízeného rehabilitačního programu a doma na něj navázali individuálním cvičením. Ve skupině B bylo 22 pacientů (14 mužů a 8 žen, průměrný věk 66 ± 8 let), kteří absolvovali jen řízený program bez následného individuálního tréninku. Ve skupině C bylo 10 pacientů (7 mužů a 3 ženy, průměrný věk 60 ± 8 let), kteří neabsolvovali rehabilitační program, ale doma intenzivně cvičili. Do skupiny D bylo zařazeno 15 pacientů (12 mužů a 3 ženy, průměrný věk 63 ± 8 let), kteří se nezúčastnili rehabilitačního programu, ani doma necvičili. Další charakteristiky jednotlivých skupin jsou uvedeny v tab. 1. Rozdíly mezi jednotlivými skupinami nebyly statisticky významné. Farmakologickou léčbu nemocných ukazuje tab. 2.

Řízený rehabilitační program probíhal na Klinice funkční diagnostiky a rehabilitace Fakultní nemocnice U svaté Anny v Brně. Nemocní, kteří souhlasili s absolvováním tohoto programu, podstoupili před jeho zahájením spiroergometrické vyšetření k nastavení úrovně aerobního cvičení. Vyšetření bylo provedeno v ranních hodinách, při ponechané medikamentózní léčbě. Vlastní vyšetření začínalo 3minutovou adaptací vsedě na veloergometru. Následovaly 2minutové zátěže od 20 W, zvyšované vždy o 20 W, v jejichž průběhu byly měřeny ventilačně respirační parametry. Ty byly sledovány přístrojem Pulmonary Function System 1070 (Med Graphics, USA). Byl hodnocen symptomy limitovaný minutový příjem kyslíku (VO_2) jako kritérium kardiorespirační funkční zdatnosti a také byla určena hodnota anaerobního prahu k nastavení vhodné intenzity zatížení. Hodnota anaerobního prahu byla pro potřeby studie vyjádřena ve W, odpovídající hodnotě tepové frekvence a stupněm Borgovy škály subjektivního vnímání namáhavosti příslušného zatížení. Během celého vyšetření včetně doby restituce byl monitorován 12svodový elektrokardiogram (Schiller CS 100, USA), v klidu a na konci každé zátěže byl měřen krevní tlak.

Vlastní rehabilitační program trval 3 měsíce, během kterých nemocní cvičili 3krát týdně 60 minut. Cvičební jednotka se skládala ze zahřívací fáze (10 minut), vlastního aerobního cvičení na veloergometru, na úrovni aerobního prahu doplněná silovým tréninkem (40 minut) a ze závěrečné fáze relaxační (10 minut).

Individuální aktivita byla doporučována jako minimálně 3krát týdně 60 minut aerobního cvičení (jízda na kole nebo na rotopedu, běh, plavání). Plnění tohoto doporučení bylo zjišťováno pouze anamnesticky od pacienta a nebylo ani kontrolováno, ani prověřováno.

Ergometrické zátěžové testy byly provedeny na přístroji Ergo-line před zařazením do studie a po 1 roce sledování, vždy s vysazenou medikací. Bylo započato zátěží 0,5 W/kg, která byla schodovitě zvyšována po 3 minutách vždy o 0,5 W/kg. Test byl ukončen při průkazu ischemie (objevení nebo prohloubení depresí ST-úseku o alespoň 0,2 mV), při dosažení průměrné maximální tepové frekvence vzhledem k věku, při vzestupu krevního tlaku nad 250/130 mmHg, při dosažení hranice subjektivního maxima. Rozdíl mezi zátěžovým testem na konci sledování a na začátku studie byl hodnocen pomocí změny těchto parametrů: celkový čas zátěže, celkově vykonaná práce, pracovní kapacita, pracovní tolerance, čas do stenokardií a deprese ST-úseku ve svodu V5 při maximální zátěži (srovnáno dle maximální zátěže vstupního testu).

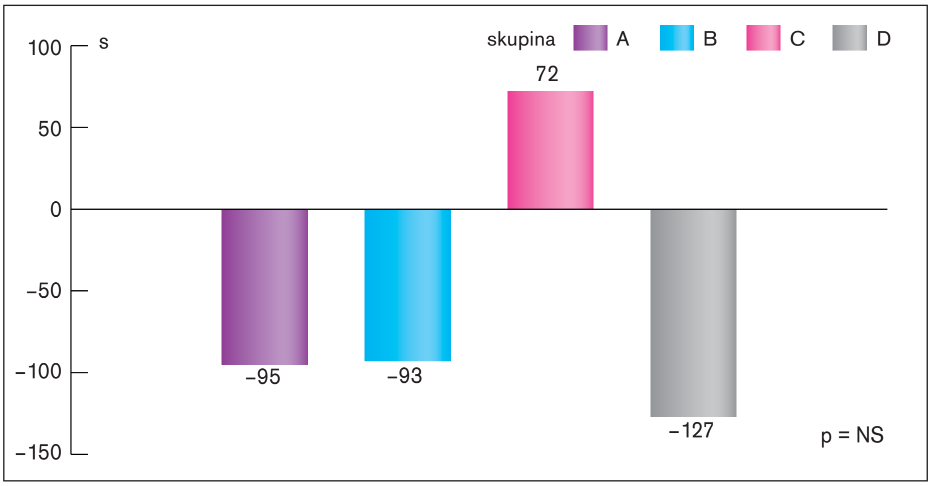
Ejekční frakce byla před zařazením do studie stanovena retrográdní levostrannou ventrikulografií.

Výsledky srovnání změny parametrů ergometrických testů nemocných jsou uvedeny jako průměry směrodatná odchylka. Výsledky jednotlivých skupin byly porovnány parametrickou statistickou metodou ANOVA. Hodnoty $p < 0{,}05$ byly považovány za významné. Normální rozložení hodnot bylo testováno pomocí Kolmogorov-Smirnovovým testem s výsledkem $p > 0{,}2$.

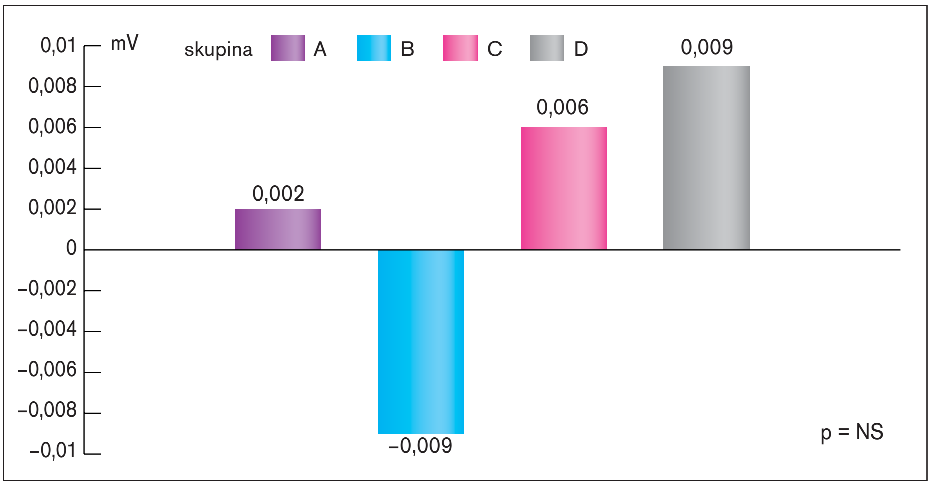
Tab. 2. Farmakologická léčba nemocných.

Skupina	salicyláty (%)	BB (%)	CaA (%)	nitráty (%)	ACEI (%)	ATII (%)	statiny (%)
A	100	94	53	53	53	12	88
B	95	100	27	68	68	0	82
C	90	100	10	70	70	10	80
D	100	93	40	80	33	0	73

BB = betablokátory, CaA = kalciový antagonisté, ACEI = antagonisté angiotenzin–konvertujícího enzymu, ATII = sartany.



Graf 3. Srovnání změn času po stenokardií během zátěžového testu na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.



Graf 4. Srovnání změn depresí ST úseku ve svodu V5 při maximální zátěži na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.

Výsledky

Vliv různých typů tréninku na změnu parametrů ergometrického zátěžového testu přehledně znázorňují grafy 1–6. Nalezené změny zátěžových testů v jednotlivých skupinách nedosáhly statistické významnosti. Nemocní cvičící od začátku individuálně (skupina C) vykazovali trend ke zlepšení ve všech hodnocených parametrech s výjimkou prohloubení deprese úseku ST ve svodu V5 při maximální zátěži (prohloubení při kontrolním testu o 0,006 ± 0,018 mV, p = NS). Při kontrolním testu dosáhli o 30 ± 108 s delší doby zátěže, vykonali o 3,7 ± 15,0 kW větší celkovou práci, dosáhli vyšších hodnot pracovní kapacity o 0,01 ± 0,52 W/kg a pracovní tolerance o 0,16 ± 0,33 W/kg a prodloužil se u nich čas do stenokardií o 72 ± 408 sekund (vše p = NS).

Nemocní, kteří absolvovali řízený program a následně individuálně cvičili (skupina A), dosáhli nevýznamně delšího celkového času zátěže (zlepšení o 26 ± 73 s), vykonali větší celkovou práci (o 4,8 ± 1 4,2 kW) a měli vyšší pracovní toleranci (o 0,03 ± 0,36 W/kg) (vše p = NS). V ostatních parametrech došlo k mírnému zhoršení – pracovní kapacita poklesla o 0,06 ± 0,48 W/kg, ST deprese ve svodu V5 při maximální zátěži se prohloubily o 0,002 ± 0,014 mV a doba do vzniku stenokardií se zkrátila o 95 ± 269 s (vše p = NS).

Pacienti necvičící vůbec (skupina D) nebo necvičící po absolvování RHB programu (skupina B) se zhoršili prakticky ve všech sledovaných parametrech. Pacienti ve skupině B vydrželi kontrolní zátěžový test o 28 ± 51 s kratší dobu, vykonali o 3,5 ± 5,9 kW menší celkovou práci, zhoršili svoji pracovní kapacitu o 0,06 ± 0,28 W/kg a pracovní toleranci o 0,08 ± 0,20 W/kg a stenokardie popisovali o 93 ± 219 s dříve (vše p = NS). Menší deprese úseku ST ve svodu V5 o 0,009 ± 0,018 mV (p = NS) je dán menší celkovou prací při kontrolním testu.

Nemocní ze skupiny D měli nižší čas zátěže o 8 ± 95 s, menší celkově vykonanou práci o 0,8 ± 13,3 kW, menší pracovní kapacitu o 0,23 ± 0,36 W/kg a pracovní toleranci o 0,07 ± 0,25 W/kg, stenokardie udávali o 127 ± 320 s dříve a deprese úseku ST ve svodu V5 se prohloubily o 0,009 ± 0,012 mV (vše p = NS).

Rozdíly mezi jednotlivými hodnocenými skupinami nebyly statisticky významné. Během obou sledovaných forem fyzického tréninku nenastala žádná závažná komplikace.

Diskuse

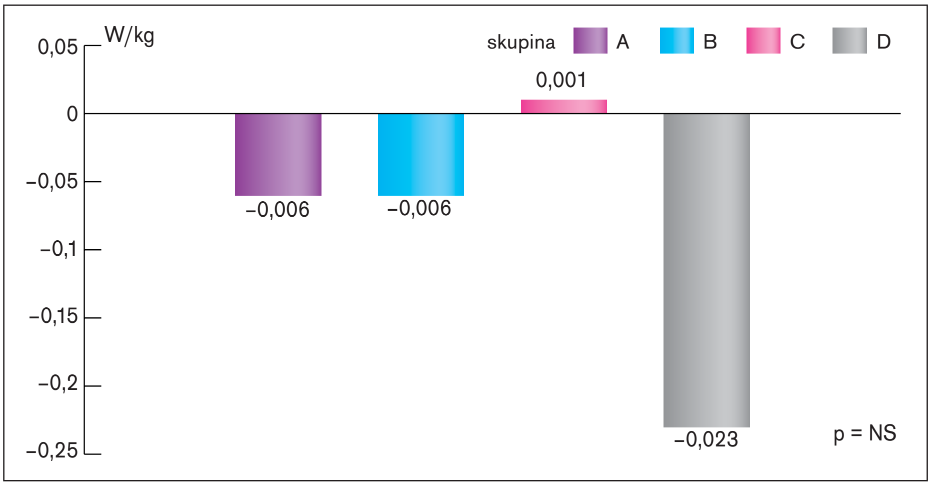
V naší práci se parametry opakovaného ergometrického zátěžového testu nemocných s chronickou ischemickou chorobou srdeční podstupující jednotlivé typy rehabilitačních programů od sebe statisticky významně nelišily. Počty nemocných a změny hodnocených parametrů nebyly dostatečně velké k dosažení statisticky významných rozdílů, nicméně byly nalezeny jasné trendy k většímu zlepšení zátěžové kapacity a tolerance u skupin nemocných cvičících intenzivně a trvale doma a to nezávisle na absolvování řízeného rehabilitačního programu.

Nebylo překvapením, že se zlepšili právě pacienti, kteří se cvičení věnují intenzivně sami. Mírně překvapil fakt, že se na výsledcích více neprojevil vstupní řízený trénink. Pravděpodobně je tomu tak z důvodů provedení kontrolních testů až 9 měsíců po ukončení řízeného tréninku. Je známo, že čím je trénink intenzivnější, tím výraznější efekt se dá očekávat na zátěžovou toleranci [21]. Zatímco se u nemocných, pokračujících po absolvování programu ve cvičení, projevil při kontrolních testech hlavně intenzivní dlouhodobý trénink, u těch pacientů, kteří cvičit přestali, byly naopak funkční parametry na úrovni, jako kdyby necvičili vůbec.

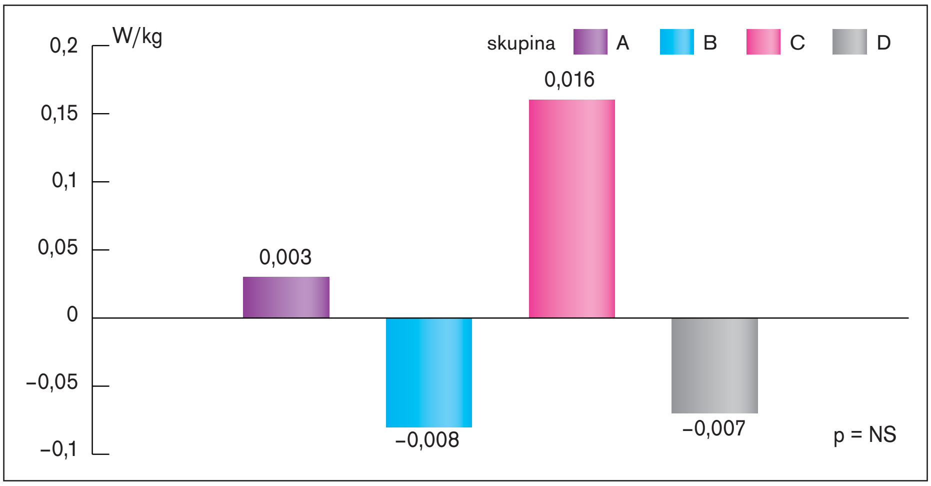
I v ostatních studiích zaměřených v minulosti na tuto problematiku byly nalezeny vlivy pravidelného cvičení na zátěžové parametry. Studie European Heart Failure Training Group, publikovaná v roce 1998 [22], uvádí statisticky významné 17% zvýšení celkového času zátěže u pravidelně cvičících pacientů, a to bez rozlišení, zda účastníci cvičili doma, nebo v nemocnici. Také udává větší účinnost u kombinace cvičení na ergometru a rytmiky oproti samotnému cvičení na ergometru.

Individuální tělesnou aktivitou se zabývali i Adachi et al [23], kteří zkoumali vliv různých intenzit tréninku na funkci levé komory. Jejich pacienti cvičili doma – měli za úkol chodit rychlou chůzí 15 minut 2krát denně, 5 dní v týdnu, po dobu 2 měsíců. Intenzitu zátěže si řídili podle tepové frekvence. U 29 nemocných po infarktu myokardu prokázali, že trénink jakékoliv intenzity zlepšuje pracovní kapacitu, ale pouze trénink o vysoké intenzitě zlepšuje funkci levé komory vyjádřenou tepovým objemem a ejekční frakcí.

Na poměrně velkém souboru 113 pacientů s ICHS, kteří cvičili pravidelně denně doma na rotopedu a své cvičení si zapisovali do přiděleného log booku, prokázali Niebauer et al [13] po 6 letech sledování 28% zvýšení pracovní kapacity a zpomalení progrese koronárních



Graf 5. Srovnání změn pracovní kapacity na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.



Graf 6. Srovnání změn pracovní tolerance na konci sledování ve srovnání se vstupním testem v jednotlivých skupinách.

stenóz. K podobným výsledkům dospěly i další studie [24]. Pravidelné cvičení neovlivňuje pouze fyzickou výkonnost, ale i celkovou kvalitu života. Focht et al [25] porovnávali 2 druhy tělesného tréninku (pouze řízený versus řízený následovaný individuálním cvičením) u 147 osob starších 50 let a dle dotazníků zjistili zlepšení kvality života (health-related quality of life) při obou typech tréninku.

Naše práce, ve shodě s výše uvedenými studiemi, ukazuje, že nejdůležitější je pravidelnost a kontinuita cvičení. Řízené rehabilitační programy mají přesto několik nezastupitelných úloh. Ukazují nemocným styl cvičení, posilováním jim umožňují dosáhnout lepší fyzické kondice, která je nutná pro další pokračování ve cvičení na dostatečné úrovni zátěže doma. Velmi významná je u pacientů, u kterých hrozí zdravotní komplikace už při malém stupni zátěže a je u nich velké riziko zdravotních komplikací, které vyžadují lékařský dohled, příp. intervenci. Jedno z možných řešení, jak spojit řízenou a individuální tělesnou aktivitu, naznačují němečtí autoři z Heidelbergu – jejich pacienti cvičili nejdříve 3 týdny intenzivně v nemocnici (6krát denně!), následně jim byl zapůjčen rotoped a cvičili individuálně doma (2krát denně po 30 minutách) s pravidelnými společnými cvičeními v nemocnici (2krát týdně). Tímto velmi intenzivním tréninkem dosáhli u svých pacientů za 12 měsíců nejenom snížení zátěží vyvolané ischemie o 54 % [26], ale prokázali i zpomalení progrese koronární aterosklerózy [20]. Rovněž zastavení progrese koronárních aterosklerotických lézí prokázali Hambrecht et al [27] u 29 chronických ischemiků pomocí 12měsíčního individuálního tréninkového programu (minimálně 30 minut denně jízdy na ergometru) zahájeného 3 týdny společného cvičení v nemocnici (6krát denně 10 minut šlapání na ergometru).

Podobně Hofman-Bang [4] nabídli svým pacientům 12měsíční individuální tréninkový program spojený s pokusem o změnu životního stylu, který zahrnoval vstupní 4týdenní „zaučení“. Na 151 nemocných po PTCA (perkutánní transluminální koronární angioplastice) ukázali zvýšení pracovní kapacity a snížení počtu hospitalizací během následujících 12 měsíců po ukončení programu. Z hlediska praktického využití mají tyto rehabilitační modely zásadní limitaci ve vstupní 3týdenní, respektive 4týdenní hospitalizaci, nicméně jistě by se podobné spojení řízené a individuální aktivity dalo přizpůsobit reálným možnostem a komfortu pacientů.

Hlavními limitacemi naší práce je malé množství nemocných v jednotlivých skupinách a krátká doba sledování. Spolu s očekávaně nevelkými změnami jednotlivých ergometrických parametrů po 1 roce sledování se nedá předpokládat statistická významnost rozdílů mezi skupinami. Vzhledem k jasným trendům je plánováno pokračování studie s větším počtem nemocných a s delší dobou sledování.

Závěr

Parametry opakovaného ergometrického zátěžového testu nemocných podstupující jednotlivé typy rehabilitačních programů se od sebe statisticky významně nelišily. Byl nalezen trend zlepšení zátěžových parametrů u skupin nemocných cvičících intenzivně a trvale doma a trend zhoršení u skupin individuálně necvičících, a to nezávisle na absolvování úvodního řízeného rehabilitačního programu. Je třeba dbát zvýšeného důrazu na informování a edukaci nemocných s ICHS ve smyslu zintenzivnění jejich pohybového režimu.

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The Effect of Regular Physical Activity on the Left Ventricle Systolic Function in Patients With Chronic Coronary Artery Disease

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Summary

The purpose of this study was to assess the influence of aerobic training on the left ventricular (LV) systolic function. Thirty patients with stable coronary artery disease, who had participated in the conducted 3-month physical training, were retrospectively divided into 2 cohorts. While patients in the cohort I (n=14) had continued training individually for 12 months, patients in the cohort II (n=16) had stopped training after finishing the conducted program. Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training program and 1 year later. The peak systolic velocities of mitral annulus (Sa) were assessed by tissue Doppler imaging for individual LV walls. In addition, to determine global LV systolic longitudinal function, the four-site mean systolic velocity was calculated (Sa glob). According to the blood supply, left ventricular walls were divided into 5 groups: A- walls supplied by nonstenotic artery; B- walls supplied by coronary artery with stenosis ≤ 50 %; C- walls supplied by coronary artery with stenosis 51-70 %; D- walls with stenosis of supplying artery 71-99 %; and E- walls with totally occluded supplying artery. In global systolic function, the follow-up values of Sa glob in cohort I were improved by 0.23±0.36 as compared with baseline values at rest, and by 1.26±0.65 cm/s at the maximal load, while the values of Sa glob in cohort II were diminished by 0.53±0.22 (p=NS), and by 1.25±0.45 cm/s ($p<0.05$), respectively. Concerning the resting regional function, the only significant difference between cohorts in follow-up changes was found in walls E: 0.37±0.60 versus −1.76±0.40 cm/s ($p<0.05$). At the maximal load, the significant difference was found only in walls A (0.16±0.84 versus −2.67±0.87 cm/s; $p<0.05$). Patients with regular 12-month physical activity improved their global left ventricle systolic function mainly due to improvement of contractility in walls supplied by a totally occluded coronary artery.

Key words

Coronary artery disease • Aerobic training • Left ventricle systolic function

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Introduction

Beneficial effects of cardiac rehabilitation (CR) on secondary prevention of patients with coronary artery disease are now well-established. The major objective benefits are an increased exercise capacity (Hambrecht *et al.* 2000) and reduced rates of cardiac events and mortality (Oldridge *et al.* 1988, Hadkell *et al.* 1994). In addition, beneficial effects on coronary risk factors – blood pressure, lipid levels, glucose metabolism, body weight, as well as on the endothelial function and psychological well-being were proved (Shephard and Balady 1999).

On the other hand, only limited data exists

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concerning the effect of CR on left ventricular (LV) function. Some authors suggest improvements in cardiac function (Belardinelli *et al.* 1996, Giannuzzi *et al.* 1997, Hambrecht *et al.* 2000, Klecha *et al.* 2007), whereas others have not found any significant differences between exercise training groups and controls (Dubach *et al.* 1997, Giannuzzi *et al.* 2003). The different results may be due to differences in intensity and duration of training, measurement techniques or patient populations. However, in majority of the studies, LV function has been evaluated by LV ejection fraction (EF) measurements. It is well known that LVEF quantification using standard two-dimensional (2D) echocardiography is strongly dependent on image quality and endocardial border delineation.

Tissue Doppler imaging (TDI) is an echocardiographic technique employing the Doppler principle to measure the velocity of myocardium. Pulsed-TDI permits quantification of regional longitudinal myocardial velocities with high temporal resolution and is feasible even in poor acoustic windows. Hence, TDI offered a potentially more accurate quantitative assessment of both regional and global LV function including even more minor changes in systolic LV function that are not detectable during 2D echocardiographic evaluation of LVEF.

The purpose of this study was to assess the influence of aerobic training on the LV systolic function using TDI measurements.

Methods

Patient population and study protocol

The study comprised 30 patients with stable coronary artery disease (proved by the coronary angiography performed before the study). All of them had participated in the conducted 3-month physical CR training. The continuation of physical training was recommended to all patients. After 1 year period, these patients were retrospectively divided into 2 cohorts. While patients in the cohort I (n=14) had continued training individually for 12 months, patients in the cohort II (n=16) had stopped training after finishing the conducted CR program.

Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training program and 1 year later. For the evaluation of regional systolic LV function, the pulsed TDI was used.

According to the blood supply, LV walls were divided into 5 groups: A- walls supplied by nonstenotic artery; B- walls supplied by coronary artery with stenosis ≤50 %; C- walls supplied by artery with stenosis 51-70 %; D- walls with stenosis of supplying coronary artery 71-99 %; and E- walls with totally occluded supplying artery.

The study was in accordance with the Declaration of Helsinki (2000) of the World Medical Association, was approved by the institutional ethics committee and written consent was obtained from each patient.

Physical training

All patients had participated in the conducted outpatient CR. The program offered 3 months of 3 times per week sessions. Each session lasted for 60 minutes and consisted of 3 different phases: 10 minutes warm-up, period of aerobic exercise on bicycle ergometer with load intensity at the level of anaerobic threshold (20 min), period of resistance training performed on combined training machine (20 min), and relaxation period (10 min). Aerobic exercise intensity was individually prescribed according to symptom-limited spiroergometry (Blood Gas Analyser, MedGraphics, USA) that was provided before training period for the evaluation of anaerobic threshold.

The 9-months individual training of cohort I consisted of regular physical activity performed for a minimum of one hour at least three times a week. As a regular physical activity the patients have been asked to choose either cycling, riding a velo-ergometer or swimming.

Echocardiography

Using commercially available equipment Philips Sonos 5500 (Andover, USA) with a 2.5 MHz transducer, echocardiographic examinations were performed in one centre by one experienced echocardiographer. 2D images of standard views and pulsed TDI of apical 4- and 2-chamber views were acquired and recorded on videotape for off-line analyses. The peak systolic velocities of myocardium adjacent to the mitral annulus (Sa) were assessed by TDI for individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine global LV systolic longitudinal function, the four-site mean systolic velocity was calculated (Sa glob). Velocities were evaluated at rest and at the maximal load.

Dobutamine echocardiography was performed in all patients. Dobutamine was infused with mechanical pump, starting at a dose of 5 µg/kg/min. At 3-minute intervals, the dose was increased incrementally to 10, 20, 30, 40 µg/kg/min until a maximal dose was reached or target heart rate was attained. Intravenous atropine was given in one bolus dose of 0.5 mg if the target heart rate was not reached. After the test has been terminated, patients were monitored until baseline condition returned.

Statistical analysis

The changes of global and regional systolic function of individual LV wall groups were compared between cohorts at rest and at the maximal load. To assess normal distribution of variables, the Kolmogorov-Smirnov test was used. An unpaired t-test and Mann-Whitney U test were applied to compare the values of parameters between cohorts; $p<0.05$ was considered statistically significant.

Results

Baseline characteristics and coronary angiography findings of patients are shown at Table 1 and 2. The majority of parameters have been similar in the two groups – just differences between the number of men and women and the difference between patients age in both cohorts have been found. No serious adverse events were found in either group during the follow-up.

Table 1. Characteristics of the study population.

Parameter	Cohort I (n = 14)		Cohort II (n = 16)	
Age (years)	60	(10)	69*	(8)
Men	13	(93 %)	8*	(50 %)
Diabetes mellitus	4	(29 %)	5	(31 %)
Hypertension	14	(100 %)	16	(100 %)
Hyperlipidemia	14	(100 %)	15	(94 %)
Previous myocardial infarction	10	(71 %)	9	(57 %)
LV EF (%)	50.4	(2.9)	47.9	(2.7)
No of stenotic arteries (≥70 %)	2.1	(0.2)	1.6	(0.2)
Medication				
Aspirin	14	(100 %)	15	(94 %)
Beta blocker	14	(100 %)	16	(100 %)
ACE inhibitor	10	(71 %)	11	(70 %)
Statin	13	(93 %)	16	(100 %)
Diuretics	4	(29 %)	5	(31 %)
Nitrates	8	(57 %)	11	(69 %)

The values are expressed as the mean supplied by standard error (in parentheses) or number (%) of subjects. LV = left ventricle; EF = ejection fraction; No = number; ACE = angiotensin-converting enzyme; * $p<0.05$ between cohorts.

Table 2. Coronary angiography finding in cohorts.

Cohort	I (n = 14)			II (n= 16)		
	LAD	LCX	RCA	LAD	LCX	RCA
no stenosis	3 (21 %)	2 (14 %)	3 (21 %)	3 (19 %)	6 (38 %)	5 (31 %)
stenosis ≤ 50	4 (29 %)	7 (50 %)	0 (0 %)	2 (13 %)	4 (25 %)	4 (25 %)
stenosis 51-70 %	2 (14 %)	2 (14 %)	3 (21 %)	1 (6 %)	1 (6 %)	2 (13 %)
stenosis 71-99 %	3 (21 %)	1 (7 %)	3 (21 %)	4 (25 %)	3 (19 %)	2 (13 %)
totally occluded	2 (14 %)	2 (14 %)	5 (36 %)	6 (38 %)	2 (13 %)	3 (19 %)

The values are expressed as number of arteries (%). LAD = left anterior descending artery; LCX = left circumflex; RCA = right coronary artery.

Table 3. Changes of Sa value after follow-up in different groups of LV walls at rest and at the maximal load.

	At rest		At the maximal load	
Cohort	**I (n = 14)**	**II (n = 16)**	**I (n = 14)**	**II (n = 16)**
Wall group				
A	-1.56±0.93	-0.86±0.38	0.16±0.84	-2.67±0.87*
B	1.29±0.63	0.62±0.58	3.83±1.13	0.56±1.05
C	-0.64±0.69	0.14±0.88	-0.42±1.02	-0.58+1.92
D	-0.09±0.86	-0.10±0.30	-2.82±1.19	-2.29±0.86
E	0.37±0.60	-1.76±0.40*	1.70±1.43	0.02±0.78
All (global function)	0.23±0.36	-0.53±0.22	1.26±0.65	-1.25±0.45*

The values are expressed as the mean supplied by standard error (in parentheses). Sa = peak systolic velocity of mitral annulus; LV = left ventricle. Wall groups: A- walls supplied by nonstenotic artery; B- walls supplied by artery with coronary stenosis ≤ 50 %; C- walls supplied by artery with stenosis 51-70 %; D- walls with stenosis of supplying artery 71-99 %; and E- walls with totally occluded supplying artery. * p<0.05 between cohorts.

The changes of Sa value after follow-up in different groups of LV walls are shown in Table 3. In global systolic function, the values of Sa glob in cohort I were improved by 0.23±0.36 as compared with baseline values at rest, and by 1.26±0.65 cm/s at the maximal load, while the values of Sa glob in cohort II were diminished by 0.53±0.22 (p=NS), and by 1.25±0.45 cm/s (p<0.05), respectively.

Concerning the resting regional function, the only significant difference between cohorts in follow-up changes was found in walls E: 0.37±0.60 versus –1.76±0.40 cm/s (p<0.05). At the maximal load, the significant difference was found only in walls A (0.16±0.84 versus –2.67±0.87 cm/s; p <0.05). Sa changes in other walls was not significant.

Discussion

Effect of CR on global LV systolic function

The present investigation suggests that long-term exercise training can improve LV systolic function in patients with coronary artery disease. Previous works have shown variable results in relation to influence of CR on the LV function (Belardinelli *et al.* 1996, Hambrecht *et al.* 2000, Giannuzzi *et al.* 2003, Klecha *et al.* 2007). The failure to assess changes in LVEF in some studies may have several reasons. It may be the result of different study populations, kind and intensity of the training programs or the measurement techniques (Webb-Peploe *et al.* 2000). Only patients with chronic heart failure or after myocardial infarction with moderate-to-severe LV dysfunction were included in the majority of studies assessing the influence of CR on LV function. In comparison with them, our patients had only slight depression of LVEF and not all of them underwent clinical myocardial infarction.

The intensity and duration of CR necessary for LV function improvement have not yet been sufficiently evaluated. In the analysis in the work of Piepoli (2004) the data suggested that only long-term duration over 28 weeks of CR may be required to reach benefits in mortality and adverse events rates. The antiremodelling effect of training with a trend towards improvement of LV functional parameters was found after 6-month training in the work of Klecha *et al.* (2007). On the other hand, the work of Hambrecht (2000) demonstrated that an intense CR program can improve resting LVEF in 2 weeks. In our work, just 1-year CR improved LV systolic function, while the 3-month training did not provide the sustained long-term functional improvement.

The utilization of LVEF, as an evaluated parameter of LV function, could be one of the main factor contributing to the failure of some previous studies to shown the effect of CR. LVEF is a load-dependent parameter and is very rough to assess expected slight changes of LV function. EF evaluated by 2D echocardiography is strongly dependent on image quality and endocardial border delineation. In contrast, TDI is robust, reproducible and may be more sensitive marker of LV longitudinal systolic function and it is feasible even in poor echocardiographic windows. Hence, TDI allows evaluation of even minor changes in LV function that are not detectable by 2D assessment. In several published data, TDI has been applied to stress echocardiography in order to overcome the limitation of only visual analysis (Cain *et al.* 2001, Fathi *et al.* 2001, Garcia *et al.* 2006, Bougault *et al.* 2008, Duzenli *et al.* 2008).

Effect of CR on regional LV systolic function

This present study is the first trial to evaluate the effect of CR on regional LV systolic function in relation to blood supply of individual LV walls. TDI was chosen for this purpose, because it permits quantification of regional longitudinal myocardial systolic velocities with a high temporal resolution and can overcome the limitation in the subjective echocardiographic evaluation of regional ventricular function (Reuss *et al.* 2005). Our data showed that the effect of CR on LV systolic function is caused mainly through the improvement of contractility in walls supplied by a totally occluded coronary artery. The effect of physical training and LV global and regional function was assessed by TDI also in the study of Deljanin-Ilic *et al.* (2007). After 6 months, LV EF increased significantly as well as the regional systolic myocardial function at the previously infarcted wall only in the training group.

Mechanisms of this training effect have not yet been established. The most likely explanation is the combination of beneficial changes in ventricular wall tension and favorable adaptation in the coronary circulation. The physical training may have beneficial effect on changes in autonomic balance toward a vagal predominance, which could limit the deleterious effects of sympathetic hyperactivity on the LV remodeling and function, analogously to treatment with beta blockers.

In patients with stable coronary artery disease, augmented delivery of blood to ischemic myocardium has been shown to take place in response to physical training (Hambrecht 2004). The beneficial effect of CR on morbidity and mortality has been attributed to the growth of collateral vessels between healthy and under-perfused myocardial regions (Shephard and Balady 1999). This theory was documented for example by work of Zbinden *et al.* (2007) where beneficial dose-response effect of 3-month endurance exercise training on collaterals has been found. However, other human studies have failed to document consistently the formation of collaterals. The main reason for different results may have been the lack of sensitivity of angiography to detect small coronary collaterals. The collateral growth and other coronary vascular changes may improve function of chronically hypoperfused myocardium.

Furthermore, CR has been shown to favourably affect blood flow rheology, thereby possible improving of myocardial perfusion. The improvement in myocardial blood flow to the infarcted area may lead to recovery of both global and regional LV function (Schuler *et al.* 1992). Although our study cannot elucidate the possible mechanism of regional functional improvement, we speculate, that combination of autonomic system changes and especially the development of collaterals may have facilitated partial functional recovery of dysfunctional but viable myocardial regions supplied by a totally occluded coronary artery.

Study limitations

Our study had several limitations. The study was retrospective, not randomized. The interpretations of results could be limited by a relatively small sample size in both cohorts. Also our study can be influenced by the difference between the number of men and women and the difference between patients age in both cohorts, because age and gender are determining factors for training effects - smaller improvements of women as well as a negative relation between age and improvement in exercise performance is known (Vanhees *et al.* 2004).

Another limitation is the fact, that the 9-months training of cohort II have been performed as an outpatient individual training without any supervision. The information about frequency and intensity has been obtained only from patient's anamnesis during their regular visits in outpatient department. However, very different types of training programmes are described in literature and in some studies, a home-based CR had no significant differences in the main outcomes compared with the centre-based programme (Jolly *et al.* 2009) or an outpatient CR led to further improvement of followed parameters in comparison to supervised CR in a hospital (Benzer *et al.* 2007).

Certainly, further research is required, especially in order to optimize the effectiveness of CR programs and to better understand the mechanisms responsible for the improvements related to CR training.

Conclusion

In our study, patients with regular 12-month physical activity improved their global left ventricle systolic function mainly due to improvement of contractility in walls supplied by a totally occluded coronary artery.

Conflict of Interest

There is no conflict of interest.

Acknowledgements
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ASSESSMENT OF THE LEFT VENTRICLE DIASTOLIC FUNCTION IN A GROUP OF PATIENTS WITH CHRONIC ISCHAEMIC HEART DISEASE AND REGULAR PHYSICAL ACTIVITY

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ABSTRACT

Aim
Assessment of the left ventricle diastolic function in a group of patients with stable coronary artery disease and regular physical training.

Methods
The study included thirty patients with stable coronary artery disease. Every patient had participated in the conducted 3-moth physical training in Department of Functional Diagnostic and Rehabilitation St. Anna Hospital. After one year the patients were retrospectively divided into two cohorts according to their physical activity. The patients in cohort C (consisting of 14 patients) continued in aerobic physical training after the end of the rehabilitation programme. The patients in cohort N (consisting of 16 patients) had stopped their training after finishing the conducted programme in St. Anne's Faculty Hospital.
The peak diastolic velocities of myocardial motion were measured at individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine global LV diastolic function, the four-site mean diastolic velocity was calculated (Ea glob, Ea/Aa glob). The velocities were evaluated at rest and at the maximal load.
According to blood supply, left ventricular walls were divided into five groups: 0 – walls supplied by non-stenotic artery; 1 – walls supplied by artery with coronary stenosis ≤ 50 %; 2 – walls supplied by artery with stenosis 51–70 %; 3 – walls with stenosis of supplying artery 71–99 %; 4 – walls with totally occluded supplying artery. For every patient the difference between the values Ea and Ea/Aa for each wall at the end of the study and the values at the beginning of the study was assessed. The values of the particular walls were divided into

Table 1
Population under study

	Cohort C	cohort N	
Age (years)	60±10	69±8	*
Number of arteries with stenosis ≥ 70 %	1.6±1.1	1.8±1.2	
DM	43 %	19 %	
MI	50 %	63 %	
Hypertension	100 %	100 %	
HLPP	100 %	94 %	
EF (%)	50.8±10.8	48.6±12.4	
Male/female	13/1	9/7	*

Explanatory notes: values are shown as average ± standard deviation; EF: LV ejection fraction; MI: myocardial infarction; DM: diabetes mellitus; HLPP: hyperlipoproteinaemia; * p<0.05 between cohorts

Table 2
Changes of the value characteristics of diastolic function

	rest						stress					
	Ea			Ea/Aa			Ea			Ea/Aa		
Cohort	C	N		C	N		C	N		C	N	
0	−0.64±2.08	−1.44±1.66		−0.02±0.14	−0.10±0.24		−0.44±2.53	−1.03±2,24		−0.14±0.25	0.04±0.27	
1	0.27±2.93	−0.26±1.37		−0.05±0.28	0.03±0.12		1.25±2.78	2.05±3.37		0.01±0,17	0.11±0.20	
2	0.59±2.62	−1.64±3.69		0.13±0.08	−0.11±0.38		0.51±2.87	0.62±4.97		0.00±0.20	0.13±0.43	
3	0.55±3.68	−0.66±1.71		0.03±0.34	0.14±0.30		−0.04±4.86	−0.48±3.00		0.09±0.57	0.25±0.57	
4	−0.48±2.77	−0.77±2.28		−0.06±0.22	0.03±0.18		**4.24±3.65**	**−0.68±2.74**	*	**0.29±0.39**	**−0.03±0.24**	*
Global function	**0.05±2.94**	**−0.89±2.01**	*	−0.02±0.26	0.02±0.26		**1.27±3.75**	**−0.13±3.20**	*	0.06±0.36	0.09±0.38	

Explanatory notes: values are shown as average ± standard deviation;* p<0.05 between cohorts; rest = investigation at rest; stress = investigation during maximal load; C = cohort C; N = cohort N; groups 0,1,2,3,4 = according to blood supply; global function = Ea global or Ea/Aa global as the average of all LV walls

5 groups according to blood supply (these 5 groups were created using coronarography).

The differences of these values at rest and stress between both cohorts of patients were statistically processed using an unpaired t-test; p<0.05 was considered statistically significant.

Results: In global diastolic function, the values of Ea global in cohort C were improved by 0.05±2.94 cm/s at rest, and by 1.27±3.75 cm/s at maximal load, while the values of Ea global in cohort N were diminished by −0.89±2.01 cm/s (p<0.05 versus cohort C), and by −0.13±3.20 cm/s; (p<0.05 versus cohort C) at maximal load.

The most important benefit with diastolic function was found in group 4 (groups with totally occluded coronary artery). The values of Ea in cohort C were improved by 4.24±3.65 cm/s, while the values in cohort N were diminished by −0.68±2.74 cm/s; (p<0.05 versus cohort C) at maximal load.

Results

The results of the other Ea values were not significant.

The Ea/Aa values in group 4 in cohort C were improved by 0.29±0.39 cm/s at maximal load, while the values of Ea/Aa in cohort N were diminished by -0.03±0.24 cm/s; ($p<0.05$ versus cohort C) at maximal load. The results of the other Ea/Aa values were not significant.

Conclusion

Our patients with 12 months' training improved their global diastolic function. The most important benefit was found in walls supplied by occluded artery.

ABBREVIATIONS USED

TDI – tissue Doppler imaging
LV – left ventricle
Sa – systolic phase of cardiac cycle
Sa´ – peak of isovolumic contraction
Ea – fast filling diastolic phase
Aa – atrium contraction end of diastolic phase
EF LV–LV ejection fraction
MI – myocardial infarction
DM – diabetes mellitus

INTRODUCTION

The effects of regular physical activity on the cardiovascular system and myocardial function are global. The risk factors are reduced (by changing the way of life, strength of thews). Heart rate and blood pressure are decreased, the peripheral venous tone is improved, and a positive influence on the left ventricle (LV) is probable.

Tissue Doppler imaging (TDI) is an echocardiographic method using the Doppler effect. Using this method it is possible to measure the velocity of myocardial motion in both systolic and diastolic phases of cardiac cycle [1]. The difference between the classic Doppler sonography and TDI is in using special filters that eliminate signals which are repulsed back by blood cells, and reversibly intensify signals that are repulsed by the myocardium (these signals are marked with high amplitude and low frequency).

There are two types of TDI: pulsed TDI and colour TDI. Using the pulsed TDI we get the characteristic curve, which consists of three main waves *(Figure 1)*. The positive Sa wave represents the systolic phase of the cardiac cycle. This wave is frequently two-phased with a first slim peak of isovolumic contraction (Sa´) and a second, wider wave of LV ejection. The first negative wave after the Sa wave is called Ea; it represents fast filling of the ventricle in the diastolic phase of the cardiac cycle. The second negative wave (Aa) grows from atrial contraction at the end of the diastolic phase of the cardiac cycle. The Aa wave is missing in the case of atrial fibrillation [2]. During exercise tests the waves Ea and Aa are often fusing [3] caused to the faster heart rate.

Figure 1. Characteristic curve of pulsed TDI.

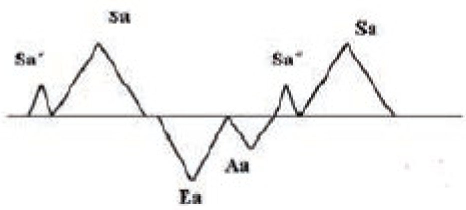

Figure 1
The characteristic curve of pulse TDI
Sa – systolic phase of cardiac cycle
Sa´-peak of isovolumic contraction
Ea – fast filling diastolic phase
Aa – atrium contraction end of diastolic phase

By measuring the amplitude of these single waves, the maximal velocity of each myocardial segment during the cardiac cycle can be evaluated. In myocardial pathologies the velocity values for each segment and also the overall value of the ventricle function are changed. The velocity of all 17 myocardial segments can be measured [4]. Physiologically, the velocities are getting higher in segments from the apex toward the heart base. TDI can be used for the evaluation of both regional and global function of both ventricles (both systolic and diastolic ventricle function). We can prove myocardial ischaemia, and reversible and non-reversible myocardial dysfunction [2]. During ischaemia the maximal Sa and Ea velocities are reduced. The change of Aa is not significant, so the Ea/Aa ratio in the ischaemic area is getting down [1].

The purpose of this study was to assess the effect of aerobic training on the left ventricular diastolic function in a group of patients with chronic ischaemic heart disease.

MATERIALS AND METHODS

The study included thirty patients with stable coronary artery disease. These patients were retrospectively divided into two cohorts with different regular physical training. The cohort C consisted of 14 patients. These patients had participated in a conducted 3-month physical training at the Department of Functional Diagnostics and Rehabilitation of St. Annes' Faculty Hospital, and after the 3 months they continued with individual training for 9 more months. The regular physical training consisted of 3 phases in 60 minutes 3 times a week. The first phase of the training is called warming-up and lasts for ten minutes. The second phase is an aerobic period and lasts for 35 minutes. This phase consists of power training and riding a bicycle ergometer. The third phase is a relaxation phase and lasts for 15 minutes. The 9-month individual training consists of regular physical activity performed for one hour at least three times a week. As a regular physical activity the patients chose one of the following sports: riding a bicycle ergometer, cycling, or swimming. The cohort N consisted of 16 patients. These patients stopped the training after having finished with the conducted programme. The cohort's characteristics are shown in *Table 1*.

At the beginning of the study coronarography was performed. According to blood supply, the left ventricular walls were divided into five groups: 0 – walls supplied by non-stenotic artery; 1 – walls supplied by artery with coronary stenosis ≤ 50 %; 2 – walls supplied by artery with stenosis 51–70 %; 3 – walls with stenosis of supplying artery 71–99 %; 4 – walls with totally occluded supplying artery.

Rest and stress dobutamine/atropine echocardiography was performed in all patients before the training programme and one year later. Three days before the rest/stress dobutamine echocardiography the beta blockers were discontinued. Using the commercially available equipment Sonos 5500 (Hewlett-Packard, US) with a 2.5 MHz transducer, echocardiography was performed in standard views – parasternal long axis, parasternal short axis (level of papillary muscles), apical 4- and 2-chamber views. The peak diastolic velocities of myocardial motion were measured at individual LV walls: septum, lateral, anterior, and inferior walls. In addition, to determine the global LV diastolic function, the four-site average diastolic velocity was calculated (Ea glob, Ea/Aa glob). The velocities were evaluated at rest and at the maximal load.

For every patient the difference between the values Ea, Ea/Aa for each wall at the end of the study and the values at the beginning of the study was assessed. The values of the particular walls were divided into 5 groups according to blood supply (these 5 groups were created using coronarography). The differences of these values during rest and maximal stress between both cohorts of patients were statistically processed using an unpaired t-test, $p<0.05$ was considered statistically significant.

RESULTS

The results are shown in *Table 2*.

In the global diastolic function, the values of Ea global in cohort C were improved by 0.05±2.94 cm/s at rest, and by 1.27±3.75 cm/s at maximal load, while the values of Ea global in cohort N were diminished by −0.89±2.01 cm/s ($p<0.05$ versus cohort C), and by −0.13±3.20 cm/s; ($p<0.05$ versus cohort C) at maximal load.

The most important benefit to the diastolic function was found in group 4 (groups with totally occluded coronary artery). The values of Ea in cohort C were improved by 4.24±3.65 cm/s, while the values in cohort N were diminished by −0.68±2.74 cm/s; ($p<0.05$ versus cohort C) at maximal load.

The results of the Ea values from other walls were not significant.

The Ea/Aa values in group 4 in cohort C were improved by 0.29±0.39 cm/s at maximal load, while the values of Ea/Aa in cohort N were diminished by −0.03±0.24 cm/s; ($p<0.05$ versus cohort C) at maximal load.

The changes of the results of the other Ea/Aa values were not significant.

In cohort C, as the stress test was performed, 12 of 14 patients had a stress-induced kinetic disorder (2 patients had negative stress tests). In cohort N, as the stress test was performed, 12 of 16 patients had a stress-induced kinetic disorder (4 patients had negative stress tests, but 2 of them had the typical stress-performed chest pain without objective kinetic disorders).

DISCUSSION

In our work we used TDI to assess changes of the LV diastolic function. In patients with chronic ischaemic heart disease we performed the maximal stress test.

The regular physical activity has a positive influence on the diastolic function of the left ventricle. In our study we found an improvement of the global diastolic function during the rest and also during the maximal load. However, our results are not the same as the results in the Yu CM study [5], which proved no progression of diastolic dysfunction in a group of physically active patients.

We have to be cautious in our conclusion of diastolic function improvement, because the age average in both cohorts is not the same. The diastolic function is known to worsen over the age [6], and the patients in cohort N were significantly older than those in cohort C. And there was also a difference between the substitution of men and women in both cohorts. Nowadays the influence of regular physical training on the progression of age-caused diastolic dysfunction is not clear. Some studies proved the influence of regular physical training [7]; similarly in the study of Arbab-Zadeh et al. [8], in which sedentary seniors versus master athletes were compared. The conclusion drawn there was that prolonged endurance training preserves ventricular compliance with aging and may help to prevent heart failure in the elderly.

However, the results of some studies are different; thus, in the study of Nottin et al. [9], in which master athletes with long-term endurance training were compared with sedentary seniors and young adult men. The authors concluded that endurance training does not prevent from the LV diastolic dysfunction.

STUDY LIMITATIONS

Our study has several limitations. The interpretations of the results may be limited by a relatively small number of patients in both cohorts. Also, our study can be influenced by the difference between the number of men and women and the difference between the patients' age in both cohorts.

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The prognostic effect of different types of cardiac rehabilitation in patients with coronary artery disease

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Aim The purpose of this study was to access and compare the prognostic effects of different types of cardiac rehabilitation (CR) in patients with chronic coronary artery disease.

Methods One hundred fifty-two patients were retrospectively divided into 4 groups according to their adherence to physical activity recommendations. Patients in groups 1 and 2 participated in the guided 3-month exercise programme. Patients in group 1 then continued with individual exercise training, while patients in the group 2 stopped exercising after finishing the guide exercise programme. Patients in group 3 participated only in individual exercise training throughout the whole follow-up period, and patients in group 4 declined all exercise recommendations and did not exercise. The prognostic outcome of different types of cardiac rehabilitation was compared among the groups. In addition, patients who participated in individual exercise training according to recommendations (cohort IT+) were compared with patients who declined these activities (cohort IT-).

Results During a median follow-up of 94 months, 33 deaths occurred: 17 cardiovascular and 16 non-cardiac deaths. A Kaplan-Meier survival analysis demonstrated significantly better survival rates for patients who followed a long-term aerobic exercise training (IT+) than for those who did not participate or who had only a short-term exercise programme (IT-) ($P = 0.009$).

Conclusion In our study, long-term exercise training had a higher impact on patient survival than short-term guided CR.

Key words *coronary artery disease – cardiac rehabilitation – prognosis – cardiovascular risk*

INTRODUCTION

The beneficial effects of cardiac rehabilitation (CR) on secondary prevention of coronary artery disease are well-established and regular physical activity, including exercise, is recommended by many guidelines[1-3]. The major objective benefits are an increased exercise capacity[4] and reduced rates of cardiac events and mortality[5]. In addition, the beneficial effects on cardiovascular risk factors – blood pressure, lipid levels, glucose metabolism, body weight, as well as on the endothelial function and psychological well-being – have also been proven[6].

The structure and intensity of CR programmes vary widely among different countries and centres[7]. However, in spite of their benefits and guideline recommendations, only a minority of eligible patients participated in and completed these programmes. Alternative home-based CR activities might help to solve the problems of the poor uptake and adherence of outpatients or inpatients to centre-based CR programmes. Furthermore, the physical activity behaviour of patients, especially their participation in walking and vigorous activities, was found to be inversely associated with the use of antidiabetic, antihypertensive, and lipid-lowering drugs[8,9].

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The purpose of this study was to assess and compare the prognostic effects of different types of aerobic exercise programmes in patients with chronic stable coronary artery disease.

PATIENTS AND METHODS

Patient population and study protocol

The study comprised 152 consecutive patients with stable coronary artery disease with at least one coronary artery stenosis of more than 50% in the luminal diameter (proved by the coronary angiogram performed before the study). The exclusion criteria were: (1) coronary artery bypass graft or coronary intervention less than 3 months before inclusion; (2) known need for future coronary revascularization; (3) unstable patients; (4) haemodynamically important valve disease; (5) non-cardiac disease adversely affecting prognosis; and (6) non-cardiac disease seriously limiting the participation in cardiac exercise programmes.

Participation in the supervised outpatient cardiac rehabilitation and individual aerobic exercise training programmes were recommended to all patients. After the follow-up, the patients were retrospectively divided into 4 groups according to their acceptance of the exercise recommendation. Patients in groups 1 and 2 participated in the guided 3-month physical exercise programme. Patients in group 1 continued to exercise individually; patients in the group 2 stopped their exercise after finishing the guided programme. Patients in group 3 participated only in an individual exercise training programme throughout the follow-up period, and patients in group 4 declined all exercise recommendations and did not exercise. For further evaluation of the effect of different types of aerobic exercise, patients who attended the supervised cardiac rehabilitation (cohort CR+, comprising patients of groups 1 and 2) were compared with patients who did not (cohort CR-, comprising patients of groups 3 and 4). Similarly, patients who participated in the individual training programme in accordance with the recommendation (cohort IT+, comprising patients of groups 1 and 3) were compared with patients who declined these activities (cohort IT-, comprising patients of groups 2 and 4).

During the follow-up period, all patients were medically treated according to the evidence-based medicine. Significant effort was spent also on motivating the patients toward non-pharmacological treatment of risk factors, including not only physical exercise, but also smoking cessation, dietary and weight recommendations. Mortality and major adverse cardiac events (MACE) were assessed during follow-up visits. The primary end point was all-cause mortality; the secondary end points were a composite of MACE, including myocardial infarction, unstable angina pectoris, coronary revascularization, and hospitalization for heart failure.

The study was in accordance with the Declaration of Helsinki (2000) of the World Medical Association, and was approved by the institutional ethics committee. Written consent was obtained from each patient.

Physical exercise

The guided programme offered 3 months of 3 times weekly sessions. Each session lasted for 60 minutes and consisted of 3 different phases: 10 minutes of warm-up, 20 minutes of aerobic exercise on a bicycle ergometer with a load intensity at the level of the anaerobic threshold, 20 minutes of resistance training on the combined training machine, and 10 minutes of relaxation.

Aerobic exercise intensity was individually prescribed according to initially performed symptom-limited spiroergometry. The protocol with intensified workload up to the symptom- limited maximum was used starting on 40W, increasing by 20W each 2 minutes. The respiratory gases were analysed under physical exercise (Blood Gas Analyser, MedGraphics, USA). The anaerobic threshold value for prescribing suitable load intensity was determined according to the corresponding value of heart rate and degrees of the Borg scale of subjective perception of load intensity.

The individual exercise training programme consisted of regular physical activity performed for a minimum of 1 hour at least 3 times per week. As a regular physical activity, patients were asked to choose cycling, riding a bicycle-ergometer or swimming.

Statistical analysis

For descriptive purposes, basic summary statistics such as mean, median, standard deviation, minimum and maximum were assessed for continuous data analysis, and absolute and relative frequencies for binary and categorical data. Groups were compared in continuous parameters by the ANOVA or Kruskal-Wallis ANOVA test if appropriate (the Kolmogorov-Smirnov test was used to analyse distribution of the data). Distribution of binary and categorical data between the groups was tested by a chi-square test.

Survival analysis (overall survival and cardiovascular survival) was performed using the Kaplan-Meier method, and groups were compared by log-rank test or by chi-square test. Cox proportional hazard regression model was used for multivariate analysis. All data were analysed at the significance level of $a = 0.05$, and all the tests were two-tailed.

RESULTS

Baseline patient characteristics are presented in tables 1 and 2. Most parameters were similar in all four groups, but there were significant differences among the groups in age, sex, and in the number of diabetic and dyslipidaemic patients. Medical treatment before the study and after follow-up is shown in tables 3 and 4. No statistically significant differences were found among the 4 groups.

During a median follow-up of 94 months (range 2-158) after inclusion, there were 33 deaths (17 cardiovascular and 16 non-cardiac deaths). The Kaplan-Meier survival curve for all four groups is shown in figure 1. Patients in group 3 had a statistically better survival than group 2 ($P = 0.042$) and group 4 ($P = 0.041$). The survival between other groups did not differ statistically. The result of an overall test comparing all patient groups bordered on statistical significance ($P = 0.067$). No significant differences in survival were found between cohorts CR + and CR- ($P = 0.948$). However, patients in cohort IT + had longer survival rates than cohort IT- ($P = 0.009$) (figure 2). Multivariate Cox regression analysis including baseline covariates (sex, age, diabetes mellitus, and dyslipidaemia) revealed group as an independent factor for survival on the borderline of statistical significance ($P = 0.057$).

The secondary end points are shown in table 5. The incidence of each of unstable angina pectoris, coronary revascularization, and hospitalization for heart failure

Table 1 Study groups characteristics: medical history

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
Age (years)	71.5 ± 10.0	71.8 ± 8.8	63.8 ± 10.3	73.9 ± 8.7	0.002*
Men	32 (100.0%)	43 (71.7%)	20 (90.9%)	27 (71.0%)	< 0.001*
BMI	27.3 ± 3.3	28.3 ± 3.0	28.3 ± 3.0	27.6 ± 3.8	0.622
LVEF (%)	48.6 ± 8.8	46.9 ± 10.1	49.5 ± 7.6	50.1 ± 11.6	0.276
No of stenotic arteries (≥ 70%)	1.5 ± 0.7	1.5 ± 0.7	1.4 ± 0.6	1.4 ± 0.6	0.526
Coronary revascularization	19 (59.4%)	29 (48.3%)	15 (68.2%)	17 (44.7%)	0.243
DM	5 (15.6%)	19 (31.7%)	2 (9.1%)	14 (36.8%)	0.028*
Hypertension	31 (96.9%)	58 (96.7%)	22 (100.0%)	37 (97.4%)	0.727
Dyslipidaemia	25 (78.1%)	53 (88.3%)	22 (100.0%)	38 (100.0%)	< 0.001*
Smoking	8 (25.0%)	8 (13.3%)	7 (31.8%)	6 (15.8%)	0.223

Values are expressed as the mean ± standard deviation or the number of subjects with the percentage in parentheses.
BMI: body mass index, LVEF: left ventricular ejection fraction, DM: diabetes mellitus, *$P < 0.05$ between groups.

Table 2 Study cohort characteristics: medical history

Parameter	Group CR+ (n = 92)	Group CR– (n = 60)	*P* value	Group IT+ (n = 54)	Group IT– (n = 98)	*P* value
Age (years)	71.7 ± 9.1	70.2 ± 10.4	0.392	68.4 ± 10.7	72.6 ± 8.7	0.007*
Men	75 (81.5%)	47 (78.3%)	0.679	52 (96.3%)	70 (71.4%)	< 0.001*
BMI	27.9 ± 3.2	27.9 ± 3.5	0.867	27.7 ± 3.2	28.0 ± 3.3	0.585
LVEF (%)	47.5 ± 9.7	49.9 ± 10.2	0.091	48.9 ± 8.3	48.1 ± 10.8	0.519
No of stenotic arteries (≥ 70%)	1.5 ± 0.7	1.4 ± 0.6	0.148	1.4 ± 0.7	1.5 ± 0.7	0.868
Coronary revascularization	48 (52.2%)	32 (53.3%)	0.999	34 (63.0%)	46 (47.0%)	0.064
DM	24 (26.1%)	16 (26.7%)	0.999	7 (13.0%)	33 (33.7%)	0.007*
Hypertension	89 (96.7%)	59 (98.3%)	0.999	53 (98.1%)	95 (96.9%)	0.999
Dyslipidaemia	78 (84.8%)	60 (100.0%)	< 0.001*	47 (87.0%)	91 (92.6%)	0.253
Smoking	16 (17.4%)	13 (21.7%)	0.532	15 (27.8%)	14 (14.3%)	0.053

Values are expressed as the mean ± standard deviation or the number of subjects with the percentage in parentheses.
CR+: patients who participated in the guided exercise programme (comprising patients of groups 1 and 2), CR– = patients who declined to participate in the guided exercise programme (comprising patients of groups 3 and 4), IT+: patients who exercised individually (comprising patients of groups 1 and 3), IT–: patients who declined individual exercise (comprising patients of groups 2 and 4), BMI: body mass index, LVEF: left ventricular ejection fraction, DM: diabetes mellitus, *$P < 0.05$ between cohorts.

Table 3 Study population characteristics: medical treatment before the study

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
ASA	31 (96.9%)	57 (95.0%)	20 (90.9%)	35 (92.1%)	0.748
Beta-blockers	29 (90.6%)	58 (96.7%)	22 (100.0%)	35 (92.1%)	0.236
ACEI	28 (87.5%)	50 (83.3%)	21 (95.5%)	28 (73.7%)	0.123
Sartans	0 (0.0%)	1 (1.7%)	1 (4.6%)	0 (0.0%)	0.393
Statins	23 (71.9%)	49 (81.7%)	19 (86.4%)	35 (92.1%)	0.146
Nitrates	24 (75.0%)	41 (68.3%)	13 (59.1%)	29 (76.3%)	0.495

Values are expressed as the number of subjects with the percentage in parentheses.
ASA: acetylsalicylic acid, ACEI: angiotensin-converting enzyme inhibitors..

Table 4 Study population characteristics: medical treatment at the end of the follow-up

Parameter	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value
ASA	31 (96.9%)	58 (96.7%)	20 (90.9%)	36 (94.7%)	0.740
Beta-blockers	30 (93.8%)	58 (96.7%)	22 (100.0%)	35 (92.1%)	0.351
ACEI	21 (65.6%)	45 (75.0%)	19 (86.4%)	25 (65.8%)	0.243
Sartans	2 (6.3%)	8 (13.3%)	4 (18.2%)	5 (13.2%)	0.572
Statins	28 (87.5%)	54 (90.0%)	20 (90.9%)	35 (92.1%)	0.935
Nitrates	18 (56.3%)	39 (65.0%)	13 (59.1%)	30 (79.0%)	0.182

Values are expressed as the number of subjects with the percentage in parentheses.
ASA: acetylsalicylic acid, ACEI: angiotensin-converting enzyme inhibitors.

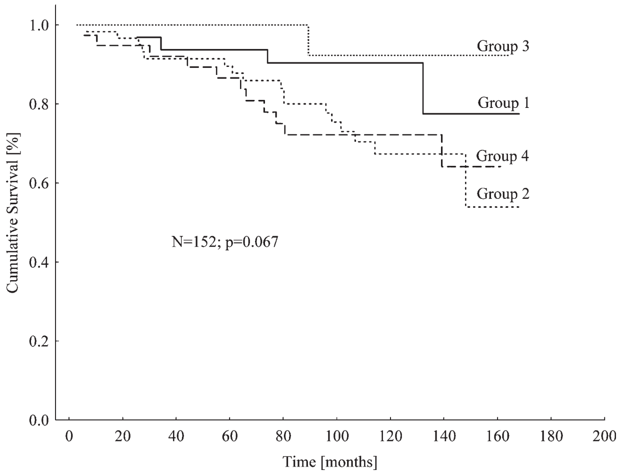

Fig. 1 Kaplan-Meier curve for patient survival according to the physical activity – a comparison of 4 groups of patients

Group 1: patients participated in the supervised 3-month physical exercise programme and continued to exercise individually, group 2: patients participated in the supervised 3-month physical training and stopped exercise after that, group 3: patients only exercised individually throughout the whole follow-up period, group 4: patients declined all exercise recommendations and did not perform any exercise activities.

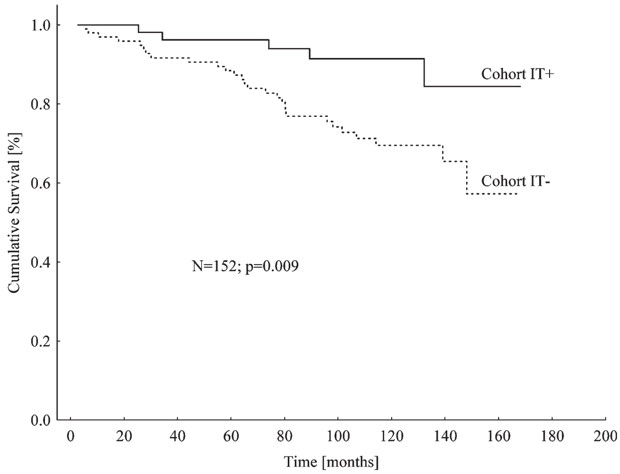

Fig. 2 Kaplan-Meier curve for patient survival according to the physical activity – a comparison of cohorts IT+ and IT-.

Cohort IT+: patients who exercised individually, cohort IT–: patients who declined individual exercise.

Table 5 Secondary end-points in groups and cohorts

	Group 1 (n = 32)	Group 2 (n = 60)	Group 3 (n = 22)	Group 4 (n = 38)	*P* value		
					Among groups	CR + vs CR–	IT + vs IT–
MI	2 (6%)	5 (8%)	1 (5%)	7 (18%)	0.249	0.275	0.149
UAP	6 (19%)	22 (37%)	1 (5%)	8 (21%)	0.008*	0.034*	0.018*
Revascularization	4 (13%)	22 (37%)	3 (14%)	13 (34%)	0.020*	0.855	0.002*
HF	0 (0%)	10 (17%)	1 (5%)	4 (11%)	0.017*	0.783	0.020*
MI + UAP + revascularization + HF	8 (25%)	36 (60%)	4 (18%)	21 (55%)	< 0.001*	0.368	< 0.001*

Values are expressed as the number of subjects with the percentage in parentheses.
CR+: patients who participated in the guided exercise programme (comprising patients of groups 1 and 2), CR–: patients who declined to participate in the supervised training (comprising patients of groups 3 and 4), IT+: patients who exercised individually (comprising patients of groups 1 and 3), IT–: patients who declined individual exercise (comprising patients of groups 2 and 4), MI: myocardial infarction, UAP: unstable angina pectoris, HF: hospitalization for heart failure, *$P < 0.05$ among groups or between cohorts.

significantly differs among the groups and was higher in cohort IT + than cohort IT-. The composite secondary end point differed significantly among groups and between cohorts IT + and IT-, but no difference was found between cohorts CR + and CR-.

DISCUSSION

The present study showed that an individual, long-term exercise programme has a higher impact on patient survival and rate of MACE than a short-term hospital-based CR programme. The potential beneficial effect of supervised exercise training is probably lost when the increased physical activity does not continue also after the guided programme is finished.

Physical activities clearly reduce the mortality of coronary artery disease patients[10]. While this is encouraging, the success of CR is largely dependent on patient adherence to exercise recommendations during both supervised exercise and self-managed exercise programmes. Unfortunately, the data show poor attendance and high dropout rates in guided CR. For example, Hansen et al.[11] followed 119 patients with coronary artery disease 18 months after inpatient rehabilitation. They found very poor adherence (27%) to the recommended minimal physical activity level during the follow-up, low habitual physical activity in the total group, and progressively worsened cardiovascular disease risk profile of the patients. Similarly, Reid et al.[12] found a significant decrease in habitual physical activity during long-term follow-up after hospital discharge in patients with coronary artery disease. The PIN study[13] showed that the benefit of CR therapy following myocardial infarction or coronary revascularization is only partially maintained during the following year. The cardiac risk factors improved initially during CR, but deteriorated over the next 12 months.

The beneficial effect of cardiac rehabilitation is nowadays well recognized. However, it remains largely obscure, which characteristics of physical activity and exercise training are the most effective. In general, recommendations of exercise training programmes need to be tailored to the individual's exercise capacity and risk profile, with the aim to reach and maintain the individually highest fitness level possible[14]. A centre-based CR has several advantages, including better exercise supervision with possibilities for correcting the intensity and type of exercise as well as addressing safety issues. On the other hand, supervised CR could be more difficult for some patients to attend. Older age and high co-morbidity are strong predictors for non-attendance[15]. A valid alternative is home-based CR. These programmes are as effective as centre-based CR, but seem hopeful in targeting higher number of patients[16-20]. Our study confirmed that long-term individual CR is a very good alterative and could be even more effective than short-time guided exercise programmes.

In several studies, such as the HF-ACTION study[21,22], exercise led only to a non-significant reduction in all-cause mortality or hospitalization. These studies failed to meet the previous expectations most probably due to non-uniform adherence to scheduled physical activity levels and a high percentage of exercise cross-over from the training group. In the HF-ACTION study, only approximately 40% of the patients in the exercise group reported weekly exercise volumes at or above the recommended level. Reasons for non-attendance usually varied - patients being "uninterested", illness, work scheduling, and transportation issues[23]. Patients are not easily convinced to permanently change their lifestyle habits. From the results of our study, it can be deduced that the initial patient enthusiasm for physical exercise and lifestyle changes and their resulting compliance with the exercise recommendations are the most important factors influencing the effect of exercise programmes.

The results of the present study are certainly influenced by the fact that it is a non-randomized study and patients were divided into groups retrospectively according to their acceptance of the exercise recommendations. Patient motivation and willingness to exercise played an important role in the study, and most probably also in their lifestyle behaviour. Other potential prognostic factors, such as dietary behaviour, weight maintenance or loss, and medication compliance, were not assessed in this study. Nevertheless, all patients were treated according to the evidence-based medicine, and a significant effort was spent on motivating the patients toward non-pharmacological treatment of risk factors, including not only physical exercise, but also dietary and weight recommendations and smoking cessation.

The interpretations of results could be limited by the relatively small sample size of the groups. The study could also be influenced by the differences in age, gender, and diabetic and dyslipidaemic patients among the groups. Younger men showed the best compliance to individual aerobic exercise, and this certainly may have influenced the results of our study.

In this study, no other outcomes than mortality and mortality were assessed. It has been reported previously that the change in aerobic capacity after CR was related to mortality. According to the study of Vanhees et al., a 1% greater increase in peak oxygen uptake (VO_2) after training was associated with a decrease in cardiovascular mortality of 2%. Peak VO_2, evaluated after a physical training programme, and its change in response to training were independent predictors for cardiovascular mortality in patients with coronary artery disease[24]. Physical training generally increases exercise capacity. The effect of our conducted 3-month training on functional capacity improvement is known and was published previously by our group[25]. However, patients in our trial had no aerobic capacity evaluation at the end of the follow-up. So that no direct comparison of the impact different training programmes on aerobic capacity is possible.

Another limitation is the fact that the outpatient individual exercise was performed without any supervision. The information about frequency and intensity was obtained only from patient anamnesis during regular visits to the outpatient department. And finally, the cut-off point of individual exercise training at a minimum duration of 1 hour at least 3 times per week was defined for the group categorization. However, very different types of exercise programmes are described in the literature and in some studies a home-based CR had no significant differences from a guided centre-based CR programme in the main outcomes[18], or an outpatient CR led to further improvements than an in-hospital supervised CR[7]. Certainly, further research is required, especially in order to optimize the effectiveness of CR programmes and to better understand the mechanisms responsible for the improvements related to CR exercise.

CONCLUSION

In our study, individual long-term exercise programmes had a higher impact on patient survival and rate of MACE than short-term hospital-based guided CR.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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