Cardiac Rehabilitation Delivery in Low and Middle-Income Countries

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Word Count: 3,160

ABSTRACT

Objective: Cardiac rehabilitation (CR) availability, program characteristics, and barriers are not well-known in low- and middle-income countries (LMICs). In this study, they were compared to high-income countries (HICs) and by CR funding source.

Methods: A cross-sectional online survey was administered to CR programs globally. Need for CR was computed using incident ischemic heart disease (IHD) estimates from the Global Burden of Disease study. General linear mixed models were performed.

Results: CR was identified in 55/138 (39.9%) LMICs; 47/55 (85.5% country response rate) countries participated and 335 (53.5% program response) surveys were initiated. There was one CR spot for every 66 IHD patients in LMICs (vs 3.4 in HICs). CR was most often paid by patients in LMICs (n=212, 65.0%) vs government in HICs (n=444, 60.2%; p<0.001). Over 85% of programs accepted guideline-indicated patients. Cardiologists (n=266, 89.3%), nurses (n=234, 79.6%; vs 544, 91.7% in HICs, p=0.001) and physiotherapists (n=233, 78.7%) were the most common providers on CR teams (mean=5.8±2.8/program). Programs offered 7.3±1.8/10 core components (vs. 7.9±1.7 in HICs, p<0.01) over 33.7±30.7 sessions (significantly greater in publicly-funded programs; p<0.001). Publicly-funded programs were more likely to have social workers and psychologists on staff, and to offer tobacco cessation and psychosocial counselling.

Conclusion: CR is only available in 40% of LMICs, but where offered is fairly consistent with guidelines. Governments should enact policies to reimburse CR so patients do not pay out-of-pocket.

Keywords: cardiac rehabilitation, health policy, myocardial infarction

Key Questions

What is already known about this subject?

There have been only four studies that have investigating the nature of cardiac rehabilitation (CR) in low- and middle-income countries (LMICs), mainly in the Latin American and Caribbean region.

What does this study add?

This is the first study to ascertain the availability of CR in LMICs. Results indicated CR is only available in 40% of LMICs, but where offered is fairly consistent with guidelines.

How might this impact on clinical practice?

More programs are required to meet the growing need for CVD care in LMICs. CR should be reimbursed to adequate levels to ensure delivery of all core components, by a reliable non-patient source.

Introduction

Cardiovascular disease (CVD) is one of the leading causes of disability globally,[1] and the highest mortality and morbidity rates are found in low- and middle-income countries (LMIC).[2] The economic burden of CVD is estimated to decrease gross domestic product by approximately seven percent in these countries.[3] Of the approximately 200 countries globally, 140 (69.0%) are LMICs,[4] and therefore there is great need for cost-effective CV secondary prevention in many countries.

Cardiac rehabilitation (CR) is a proven model of care for secondary prevention. It is comprised of several core components, delivered by a multi-disciplinary team.[5] Participation in CR reduces CVD mortality and hospital re-admission by approximately 20%, as well as improves quality of life,[6] with more CR associated with better outcomes. Accordingly, it is a recommendation in clinical practice guidelines for CVD,[7] revascularization,[8,9] and heart failure (HF)[10] patients. Unfortunately, however, it is grossly under-used, particularly in LMICs where CVD is at its' worst.[11,12] This is despite that the World Health Organization (WHO) recommends CR as a priority intervention for prevention and control of CVD,[13] and their Rehabilitation 2030 call to action (https://www.who.int/disabilities/care/rehab-2030/en/).

A review of literature revealed CR exists in only 23% of LMICS,[11] however to our knowledge there has been no primary study to ascertain availability in LMICs. Moreover, our recent review of the literature[14] revealed there have only been four publications describing the nature of CR programs in LMICs;[15–18] these publications describe CR in only ten (18.2%) of the 55 LMICs known to have CR. What is known is largely concentrated in the Latin American region, and results suggested differential costs by funding source, with many patients paying out-of-pocket. But considerable consistency in the nature of healthcare professionals (HCPs) on the CR team,

accepted indications, and delivery of core components was found. Therefore, the objectives of this study were to characterize the: (1) availability and density of CR, (2) nature of CR programs, as well as (3) barriers to CR delivery in LMICs, and compare these (a) to high-income countries (HIC), and (b) by funding source.

Methods

Design & Procedure

This research was quantitative and cross-sectional in design.

Study methods are outlined in detail elsewhere.[19,20] In brief, first, a list of all countries globally was compiled. Whether CR services were available in each country or not was ascertained through previous reviews,[11,12] communication with major CR and cardiology societies, key informants and the web.

For each country identified to offer CR, identified leaders were sent an e-mail requesting their collaboration to: (a) identify the total number of programs in their country and (b) administer the survey to each program identified.

The lead clinician at each program identified was emailed requesting their completion of the survey. Informed consent was secured through an online form. Data were collected through REDCap from June 2016-July 2017.

Sample

The sample consisted of all CR programs identified in the world, that offer services to patients following an acute cardiac event or hospitalization (i.e., Phase II). The inclusion criteria were CR programs that offered: (1) initial assessment, (2) structured exercise (supervised or not), and (3) at least one other strategy to control CV risk factors. All programs were contacted in countries

known to have ≤350 CR programs. Where more existed, a random sub-sample of 250 were contacted.

Measures

Development of the survey is described in detail elsewhere,[21] and it is available elsewhere.[19] In short, items were based on previous national/regional CR programs surveys (e.g., [16,22,23]). Items included country, program funding source, capacity, HCPs on the CR team, accepted indications, elements delivered, dose, barriers to delivery, as well as delivery of alternative models.

Country income classification was defined based on World Bank definitions of gross national income per capita: high income was $12,236 or more; lower-middle income was $1,006 - $3995; upper-middle income $3996 - $12,235; low income was $1,005 or lower.[4]

Program capacity was defined as the median number of patients a program could serve annually; this was also multiplied by the number of programs in the country (ascertained from champion) to determine national CR capacity. National density was national capacity divided by 2016 estimated incidence of ischemic heart disease (IHD) (ascertained from Global Burden of Disease study).[24] Finally, unmet need was number of incident IHD patients minus number of spots / year (i.e., capacity).

Respondents were provided five options for funding sources, and instructed to check all that apply. “Other” responses were categorized, and classified as private or public sources (e.g., foundations classified as private). To categorize funding source, respondents that selected the “patient” and/or “private health insurance” options only were categorized as “private”; those that selected the “social security/government” and/or “hospital/clincial center” options only were

classified as “public”; those that selected one or more of both the above private and public response options were categorized as “hybrid”. National funding source was also computed, classified as the most frequent of the three options from all responses in a given country. Costs were converted using purchasing power parity conversions (2016 USD).[25]

Data analysis

IBM SPSS version 24 were used for analysis, and $p<0.05$ considered significant. All initiated surveys were included. The number of responses for each question varied due to missing data (e.g., respondent did not answer a question due to lack of willingness or potential inapplicability, use of skip logic); for descriptive analyses, percentages were computed with the denominator being the number of responses for a specific item.

Descriptive statistics were applied for all closed-ended items in the survey. All open-ended responses were coded / categorized. The nature of CR services and barriers were compared by country income classification and funding source via generalized linear mixed models where possible (treating country as a higher-order variable), otherwise bivariate analyses were computed as applicable (e.g., chi-square tests); non-parametric tests were used where variables were not normally distributed (i.e., Mann-Whitney U).

Results

As shown in Supplementary Table 1 and Figure 1, 55/138 (39.9%) LMICs in the world were found to offer CR, of which data were collected in 47 (85.5% country response rate). Of these, two (of 5 LICs with CR; 40.0%) were LICs, 15 (of 17; 88.2%) were lower-MICs and 30 (of 33; 90.9%) were upper-MICs. Overall, 335 (53.5% program response rate; shown by income classification in Supplementary Table 1) surveys were initiated in LMICs, and 747 (27.2%

response) in HICs (see [19]). There was a mean of 6.1±13.3 (standard deviation; median=1) surveys per LMIC.

CR Density in LMICs

The year the first program was initiated by country is reported elsewhere,[19] with the first program opening in a LMIC in 1944 in Mexico, and 240 (77.4%) programs in LMICs opening since 2000 (of which 78 were in China). Worldwide, CR exists in 56 (86.2%) of the 67 HICs (this is significantly greater than LMICs; $X^2=37.3$, $p<0.001$), 49 (47.1%) of the 106 MICs, and in five (16.7%) of the 30 LICs (Supplementary Table 1).

National CR density was also reported elsewhere (in countries where CR exists; IHD incidence in countries without CR [i.e., no density] is also shown there).[20] Results showed wide variability across LMICs, with on average one spot per 53 incident IHD patients (308 in LICs, 274 in lower-MICs and 30 in upper-MICs). Density was greatest in Georgia (one CR spot per two incident IHD patients) and lowest in Nigeria (one spot per 4,480). Median national density in HICs was one spot per five patients. The ranking of countries based on CR density is also shown elsewhere (lower scores reflective of better density);[20] of 86 countries with data available, the mean rank for LICs was 66, and 61 for MICs. The top 25 countries were all HICs, except the following three MICs: Georgia (8th), Argentina (17th), and Colombia (22nd). Overall, counting zero spots for LMIC countries without CR, there was on average one CR spot per 66 incident IHD patients across all LMICs. Supplementary Table 1 also displays unmet CR need.

CR Indications Accepted

The three most commonly-accepted indications (acute coronary syndrome and revascularization patients) were consistent in LMICs and HICs, and with guidelines (HF ~90%; Supplementary Table 2; data shown by country elsewhere).[19] Valve procedures and heart transplant patients were significantly more likely to be accepted by programs in HICs than LMICs, and rheumatic heart disease was more-readily accepted in LMICs.

Three-quarters of programs in LMICs accepted patients at high-risk of CVD or with diabetes as a primary indication (Supplementary Table 2). Programs in LMICs were significantly more likely to accept these primary diagnoses, as well as patients with lung disease than programs in HICs. Other accepted indications reported by programs in LMICs were syncope (n=19, 29.2%), bariatric/obesity (n=16, 24.6%), and kidney disease (n=7, 10.8%) patients.

CR Providers

The most commonly-reported responsible clinician was some type of physician (e.g., cardiologist, physiatrist, sports medicine) in 254 (81.3%) LMIC programs, and in 428 (63.7%) HIC programs (X^2=31.45, p=<0.001). The most commonly-present HCP type during exercise sessions was physiotherapists (n=185, 72.0%) in LMICs, and in HICs (n=392, 73.3%). The most common HCPs found on CR teams in LMICs were cardiologists, nurses, and physiotherapists; in HICs this was nurses, dietitians, and physiotherapists (Supplementary Table 3; data shown by country elsewhere).[19] Two-thirds of programs had an administrative assistant, and one-fifth a community healthcare worker. Fifty-seven (19.0%) programs had some type of mental health professional (i..e, psychologist, psychiatrist or social worker). Other HCPs on the CR team were physicians of other specialties (n=14, 21.2%), other allied HCP (n=9, 13.6%), and generalist physicians (n=8, 12.1%). CR programs in LMICs were significantly more likely to have

physicians on staff, whereas in HICs were significantly more likely to have nurses, dietitians, social workers, pharmacists, and administrative assistants on the CR team than LMICs. Programs on average had six HCPs, with no significant difference by country income classification.

CR Elements

Elements delivered are shown in Supplementary Table 4 by country income classification (data shown by country elsewhere).[19] Initial assessment was the most frequently-delivered core component (reflective of inclusion criteria), followed by management of cardiovascular risk factors and patient education in LMICs; this was similar in HICs. Eighty percent of programs offered supervised exercise training.

Initial functional capacity assessment was more commonly by a stress test in LMICs, but not in HICs. Depression screening, nutrition counseling, stress management, tobacco cessation interventions, return-to-work counselling, and communication with the primary care provider were provided significantly more often by programs in HICs, with a significantly greater number of core components delivered in HICs than LMICs (although programs in LMICs more often offered "other" elements such as family education, and complementary/alternative medicine). Patients were significantly more likely to have an individual consult with a physician in LMICs, but with a nurse in HICs. There was more follow-up post-program in LMICs than HICs, and a trend towards more women-only classes (almost one in five programs).

CR Dose

Table 1 shows the greater session frequency, and hence total number of sessions and overall "dose" in CR programs in LMICs compared to HICs. Median hours / program was 26.5 (Q25-Q75=10-42) in LMICs.

Alternate Models of CR Delivery

Sixty-six (21.5%) programs in LMICs offered an alternative model of CR delivery than supervised clinic-based care, and 219 (36.0%) programs in HICs offered them ($p<0.31$).

Barriers to CR Delivery

What resources programs would need in order to increase capacity for both home-based and community-based programs are shown in Figure 2. Table 2 displays program ratings of barriers to delivery of all models faced by CR programs in LMICs and HICs.

Costs and Sources of Funding for CR

Respondents were requested to estimate the cost to treat one patient for a full program. Using PPP, the median cost was $718.24 (Q25-Q75=$337-1,232) in LMICs and $1,267 (Q25-Q75=$581-2,427) in HICs (Mann-Whitney U $p<0.001$).

Figure 1 displays the most common source of funding for CR by country in LMICs (reported by country elsewhere).[26] Funding sources in LMICs and HICs are summarized in Table 3. Significantly more programs were funded by patients or private health insurance in LMICs than HICs, with more programs funded by clinical centres in HICs. Other sources of funding were also more common in HICs, which included research funding/universities, veteran programs, and charity foundations.

As shown, patients were the most common CR payers in LMICs, paying some or all of the program cost (mean=49.3±38.4%) in 2/3rds of programs. Using PPP, the median cost to patients for a complete program when they paid was $338.29 (Q25-Q75=$101-814) in LMICs and $244.86 (Q25-Q75=142-596) in HICS (p=0.72; not taking into consideration transportation costs or time off work).

Supplementary Tables 2-4 and Tables 1-3 display CR program characteristics by funding source in LMICs. As shown in Supplementary Table 2, there were no significant differences in cardiac indications accepted by funding source, but privately-funded programs were significantly more likely than public programs to accept high-risk primary prevention patients. As shown in Supplementary Table 3, in terms of HCPs on staff, publicly-funded programs had significantly more psychologists, pharmacists, and social workers, and privately-funded programs had more administrative assistants.

As shown in Supplementary Table 4, privately-funded programs were significantly more likely than public programs to communicate with a patients' primary care provider and offer resistance training, however they were least likely to offer tobacco cessation interventions. Public programs were significantly more likely than private programs to offer individual consults with a nurse and psychological counselling. There were no differences observed in total elements offered by funding source.

As shown in Table 1, publicly-funded programs were of significantly longer duration than those funded by other means, resulting in significantly greater overall CR dose. Finally, as shown in

Table 2, patient referral was a significantly greater barrier in privately-funded programs, while publicly-funded programs experienced significantly more human, space, and equipment barriers.

Discussion

CR supply in LMICs is poor, with only ~40% of LMICs having any CR programs (with particularly low availability in LICs [only 5 programs globally, and hence results are primarily generalizable to MICs] and Africa [only 32 programs]). Where it is found, there is grossly insufficient capacity to meet the burden of disease. Available CR programs in MICs offer fewer core components; return-to-work counselling, stress management, and tobacco cessation interventions services should be offered more universally, particularly as they would be highly relevant to patients in LMICs. Programs in MICs had on average six staff, most commonly cardiologists, nurses, physiotherapists, and dietitians, offering on average 33 hours of CR to each patient over three months.

Of the 92 countries globally without CR, over 90% are LMICs. Across all LMICs, 14,766,930 more CR spots are needed annually to treat all incident IHD cases (vs only ~3.5 million needed across HICs),[20] and even more spots would be needed to treat those with HF, among other indications. While IHD burden is still lower in LMICs than HICs, it is rapidly increasing. Clearly capacity needs to be increased. It was surprising that the programs that do exist were so comprehensive, and expensive (e.g., more use of stress tests, physicians), with a comparable staffing complement to HICs (i.e., number), as it was expected programs would be delivering the basics in an affordable manner so as to be feasible and reach as many patients as possible. This could be due to the methods of program identification in the study, or the motivation of profit given programs are more often privately-funded.

While there was a comparable number of staff on CR teams in HICs and MICs, the type of staff differed, with in particular more physician contact in MICs. This could be due to lower labour costs in LMICs, or that it is cardiologists that have the capability/resources/position of opening programs in these settings. While some guidelines recommend physicians be a major part of CR team, not all do.[5] Task-shifting represents an important avenue to reduce the cost of CR delivery in LMICs. The International Council of Cardiovascular Prevention and Rehabilitation offers a certification program for teaching students, community healthcare workers and regulated HCPs alike how to deliver all core components in low-resource settings (http://globalcardiacrehab.com/training-opportunities/certification/).

Cost to deliver CR was significantly lower in MICs compared to HICs (consistent with most healthcare costs),[27] yet still does not appear affordable when juxtaposed against healthcare expenditure per capita in LMICs which is $455.39.[28] Patients paid part of the cost of CR in two-thirds of programs, with the average cost to patients being $570.32USDPPP/program. Given the median annual income in LMICs is $833 USD (2013 purchasing power parity),[29] this is unaffordable. This would lead to physician failure to refer, which was the most common CR barrier in LMICs (as also reported in a recent review),[12] as well as failure of patients to initiate CR or where they do, to dropout (such that although a higher dose of CR is prescribed in LMICs, patients are likely actually receiving a much lower dose). Indeed, patient or private funding sources were significantly more common in LMICs than HICs, consistent with the fact that there is more public funding of health systems in HICs than LMICs.[27] Funding source had an impact on indications accepted (non-cardiac), dose, as well as type (but not total number) of HCPs on staff, and components offered. Publicly-funded programs do appear to be of higher quality in terms of structure. Clearly, advocacy for public reimbursement is much needed.[30]

Limitations

First, some programs may not have been identified, especially in LICs where they may not have a website or published research, and in countries where no society or champion was identified. Therefore, availability, capacity, and density could be somewhat under-estimated. Moreover, due to our inclusion criteria and definition of CR (which stem from HICs), chronic disease management programs or clinics which are less comprehensive (e.g., no exercise) would not be represented. Second, though a high response rate at the country-level of 85% was achieved, response rates among programs within LMICs was just over 50%, and hence there may be some bias. However, the response rate is considered quite good for online surveys, and ultimately the sample was comprised of over half of CR programs in LMICs globally.

Third, related to measurement, information on programs was reported by staff, and while responses were confidential, respondents may have responded in a manner that reflected what they know is recommended in guidelines (i.e., socially-desirable responding). So for example, the number of elements delivered may be higher than reality. Moreover, while the survey was pilot-tested, items were not validated through verification of responses in a random sub-sample of programs. The cost items in particular should be interpreted with caution. They were not sufficiently detailed to capture what types of costs respondents included in their estimates and how they were counted, and again were not validated against actual costs.

Finally, results of the study cannot be used to draw conclusions regarding whether the programs as delivered improve patient outcomes, as that would require investigation of patient-level data. Only the structure and processes of programs were considered.

In conclusion, CR remains largely unavailable in the majority of LMICs. Where it exists, CR is quite consistent with guideline recommendations even from HICs, but is largely inaccessible to patients for reasons of capacity and finance. Increasing CR reimbursement, task-shifting, as well as offering more home-based programs could mitigate these barriers.

Acknowledgments:

On behalf of the International Council of Cardiovascular Prevention and Rehabilitation through which this study was undertaken, the Global CR Program Survey Investigators are grateful to all other national champions who collaborated to identify and reach programs in their low and middle-income country or region, namely: Eduardo Rivas-Estany, Richard Salmon, Lela Mashkhulia, Basuni Radi, Hermes Lomeli, Eleonora Vataman, Rosalia Fernandez, Voja Giga, Aashish Contractor, and Jamal Uddin. We thank the Statistical Consulting Service of the Institute for Social Research, York University for statistical help and advice. We also thank the following associations for assisting with program identification: the Africa Heart Network, the Brazilian Society of Cardiorespiratory Physiotherapy, the International Society of Physical and Rehabilitation Medicine, and the World Heart Federation (who also formally endorsed the study protocol). Dr. Derman reports some financial activities that were outside the submitted work

Funding

This project was supported by a research grant from York University's Faculty of Health. Funding was used to translate the survey into Spanish and Chinese character.

Contributorship Statement

SLG, FLJ, KT, and MS conceived and designed the research. EP and SLG preformed statistical analysis and drafted the manuscript. SLG handled funding and supervision. All authors contributed to the acquisition of the data and made critical revisions to the manuscript. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Competing Interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and have the following declarations. W.D. received research grants from the International Olympic Committee and International Paralympic Committee and personal fees from the Adcock Ingram

Pain Advisory Board and the Ossur South Africa Advisory Board. All other authors declare no financial or personal interests.

Ethical Approval: The study was exempted from ethics approval by York University's Office of Research Ethics and Mayo Clinic's Institutional Review Board. All participants gave informed consent before intiating the survey.

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Figure 1: Most common cardiac rehabilitation funders in low-and middle-income countries*

* Based on most frequent of the 3 funding sources.CR=cardiac rehabilitation

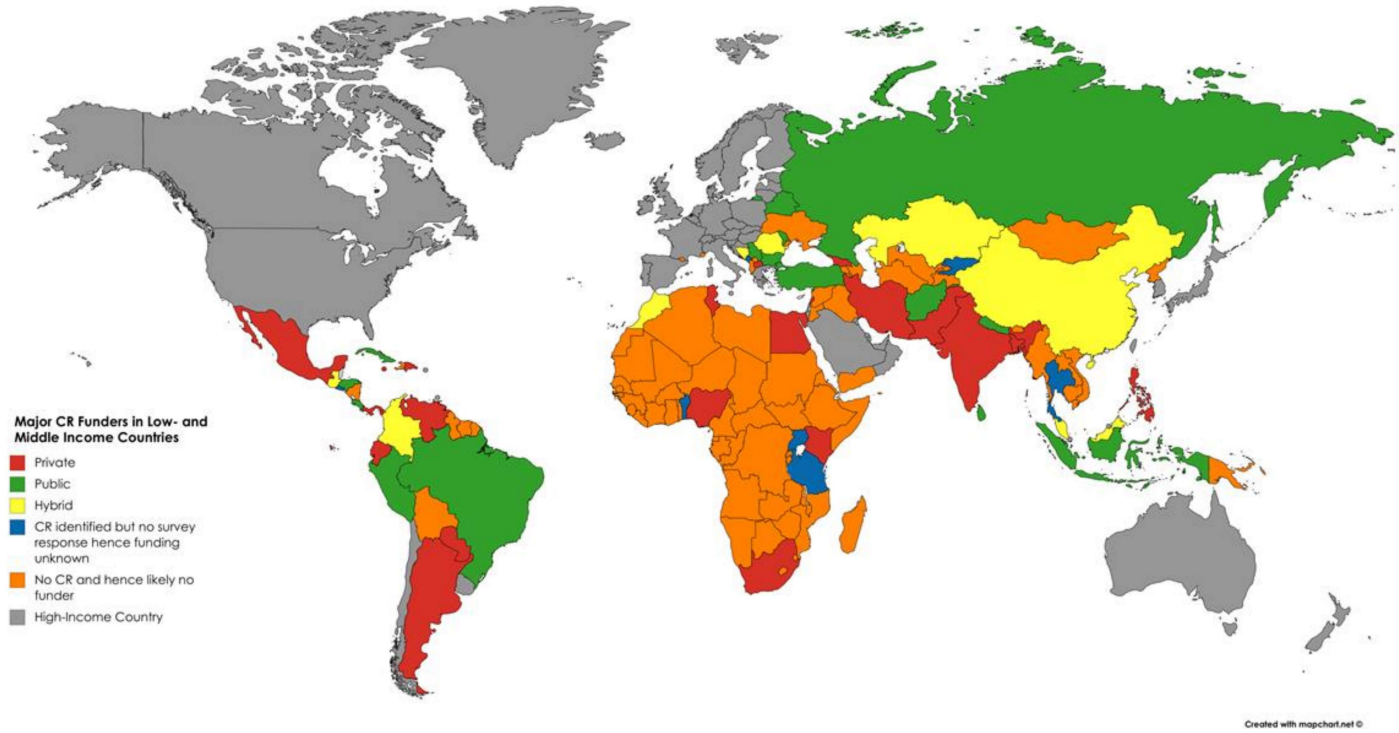

Figure 2: Resources required to increase alternative model delivery capacity in low- and middle-income countries

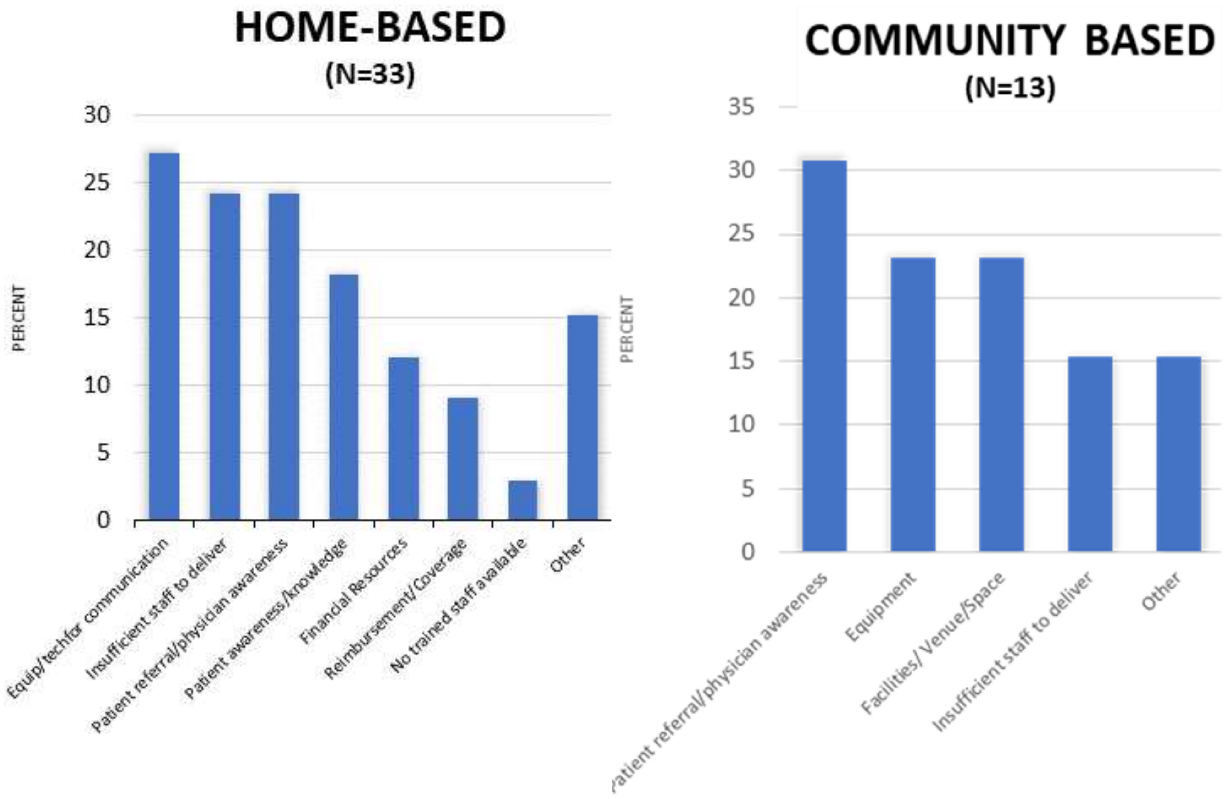

Table 1: Mean Cardiac Rehabilitation Dose (± standard deviation) by Country Income Classification and Funding Source, N=1082

	LMIC				**HIC** (n=747)	**p***
	Private (n=103)	Public (n=115)	Hybrid (n=108)	Total† (n=326)‖		
Duration (weeks)	10.8±6.9	14.1±13.5¶	10.8±9.6	11.7±10.2†† †	10.4±9.0	0.07
Frequency (per week)	2.9±1.0	2.8±1.3	2.8±1.2	2.8±1.1	2.4±1.1	<0.001
Total Sessions / program	31.0±19.7	42.2±44.0 ¶	29.4±25.1	33.7±30.7 †††	25.9±24.9	<0.001
Minutes (per session)	56.7±19.5	54.8±24.6	57.4±20.8	56.4±21.5	60.0±17.7	<0.01
Total hours/program	29.3±20.1	43.2±52.4¶	28.7±24.7	33.2±34.5†† †	26.6±25.2	<0.001

‖respondents did not provide information on funding source for CR in 9/335 surveys.
*Mann-Whitney U was used to test for significant differences in LMICs versus HICs.
† p< 0.05; †† p< 0.01; ††† p< 0.001 for Generalized Linear Mixed Models testing for significant differences by most common funding source;
For pairwise comparisons: one symbol=p<0.05; two symbols=p<0.01; 3 symbols=p<0.001
¶Significantly different from all funding sources (p<0.001).
HIC= high-income country; LMIC= low- and middle-income country

Table 2: Barriers to Cardiac Rehabilitation Delivery by Income Classification and Funding Source, N=1082

	LMIC				HIC (n=747)	p*
	Private (n=103)	Public (n=115)	Hybrid (n=108)	Total† (n=326)‖		
Patient Referral	4.2±1.3ǂǂ	3.4±1.5ǂǂ	3.7±1.4	3.8±1.4††	3.1±1.5	0.001
Financial Resources	3.4±1.5	3.5±1.5	3.6±1.4	3.5±1.5	3.5±1.4	0.91
Human Resources	2.5±1.4¶	3.4±1.4	3.0±1.4	3.0±1.5†††	3.3±1.4	0.74
Space	2.4±1.4ǂ	3.0±1.5ǂ	2.7±1.4	2.7±1.5†	2.8±1.5	0.38
Equipment	2.1±1.3ǂǂ	2.9±1.5ǂǂ	2.5±1.4	2.5±1.4††	2.4±1.3	0.14

Note: mean and standard deviations are shown, with scores ranging from 1 "this is definitely not an issue" to 5 "this is a major issue".

‖respondents did not provide information on funding source for CR in 9/335 surveys.

*Generalized Linear Mixed Models were used to test for significant differences in LMICs versus HICs.

† p< 0.05; †† p< 0.01; ††† p< 0.001 for Generalized Linear Mixed Models testing for significant differences by most common funding source;

For pairwise comparisons ǂ=p<0.05; ǂǂ=p<0.01; ǂǂǂ=p<0.001

¶Significantly different from all funding sources (p<0.001).

HIC= high-income country; LMIC= low- and middle-income country

Table 3: Sources of Cardiac Rehabilitation Program Funding by Country Income Classification, N=1082

n (%)	**LMIC** (n=335)	**HIC** (n=747)	**p***
Patient	212 (65.0%)	184 (24.9%)	<0.001
Social Security / Government	179 (54.9%)	444 (60.2%)	0.11
Hospital / Clinical Center	61 (18.7%)	250 (33.9%)	<0.001
Private Health Insurance	105 (32.2%)	167 (22.6%)	0.001
Other	6 (1.8%)	48 (6.5%)	0.001

*chi-square tests were used to test for significant differences in LMICs versus HICs
HIC= high-income country; LMIC= low- and middle-income country.

Supplementary Table 1: Availability of Cardiac Rehabilitation Programs in Low- and Middle-Income Countries, Response Rate, and Unmet Need

Income Classification Country	Number of Responses	Number of Programs	Response Rate	Unmet CR Need*
Upper Middle-Income				
Albania	0	0	-	9,490
Algeria	1	1	100·0%	-
Argentina	3	23	13·0%	76,357
Azerbaijan	0	0	-	28,593
Belarus	1	5	20·0%	87,374
Belize	0	0	-	596
Bosnia and Herzegovina	1	1	100·0%	17,068
Botswana	0	0	-	3,569
Brazil	30	75	40·0%	523,662
Bulgaria	1	1	100·0%	52,871
China	83	216	37·5%	3,034,003
Colombia	48	50	96·0%	55,745
Costa Rica	6	6	100·0%	7,568
Cuba	8	8	100·0%	48,349
Dominica	0	0	-	209
Dominican Republic	1	2	50·0%	193,919
Ecuador	2	5	40·0%	26,096
Equatorial Guinea	0	0	-	1,105
Fiji	0	0	-	1,631
Gabon	0	0	-	2,272
Georgia	13	17	76·5%	6,288
Grenada	0	1	0·0%	-
Guyana	0	0	-	1,814
Iran	14	34	41·2%	219,007
Iraq	0	0	-	117,130
Jamaica	1	3	33·3%	7,846
Kazakhstan	1	1	100·0%	57,125
Lebanon	1	1	100·0%	27,333
Libya	0	0	-	20,254
Macedonia, FYR	1	1	100·0%	8,285
Malaysia	4	6	66·7%	84,724
Maldives	0	0	-	625
Marshall Islands	0	0	-	98
Mauritius	1	1	100·0%	107,880
Mexico	9	24	37·5%	155,348
Montenegro	0	1	0·0%	2,964
Nambia	0	0	-	3,412

Nauru	0	0	-	-
Panama	1	1	100·0%	4,959
Paraguay	3	3	100·0%	14,292
Peru	7	10	70·0%	47,467
Romania	2	3	66·7%	119,335
Russia	3	-	-	1,222,142
Saint Lucia	0	0	-	288
Saint Vincent and Grenadines	0	0	-	296
Samoa	0	0	-	299
Serbia	2	2	100·0%	37,125
South Africa	14	23	60·8%	107,880
Suriname	0	0	-	1,468
Thailand	0	5	0·0%	-
Tonga	0	0	-	168
Turkey	9	10	90·0%	334,117
Turkmenistan	0	0	-	9,388
Tuvalu	0	0	-	-
Venezuela	8	9	88·9%	44,108
Program response rate in upper-MICs (30/33 countries with CR; 90·9% country response rate)	279	549	50·3%	-
Total Unmet Need in Upper-MICs	-	-	-	6,933,942
Lower Middle-Income				
Angola	0	0	-	24,579
Armenia	0	0	-	11,125
Bangladesh	1	1	100·0%	409,010
Bhutan	0	0	-	1,319
Bolivia	0	0	-	19,423
Cambodia	0	0	-	22,764
Cameroon	0	0	-	25,761
Cape Verde	0	0	-	965
Congo	0	0	-	5,921
Cote d'Ivoire	0	0	-	31,106
Djibouti	0	0	-	1,407
Egypt	2	2	100·0%	369,288
El Salvador	0	2	0·0%	-
Federated States of Micronesia	0	0	-	147
Ghana	0	0	-	36,001
Guatemala	2	2	100·0%	13,551
Honduras	1	2	50·0%	10,899
India	18	23	78·3%	3,304,474

Indonesia	10	13	76·9%	65,376
Jordan	0	0	-	22,639
Kenya	1	3	33·3%	55,114
Kiribati	0	0	-	162
Kosovo	0	0	-	-
Kyrgyzstan	0	1	0·0%	-
Laos	0	0	-	10,390
Lesotho	0	0	-	2,997
Mauritania	0	0	-	5,612
Moldova	1	1	100·0%	20,976
Mongolia	1	1	100·0%	5,241
Morocco	1	1	100·0%	156,088
Myanmar	0	0	-	108,283
Nicaragua	0	0	-	7,341
Nigeria	1	1	100·0%	223,944
Pakistan	2	4	50·0%	616,146
Palestine	0	0	-	-
Papua New Guinea	0	0	-	11,091
Philippines	10	10	100·0%	211,507
Sao Tome and Principe	0	0	-	263
Solomon Islands	0	0	-	753
Sri Lanka	2	4	50·0%	66,507
Sudan	0	0	-	111,063
Swaziland	0	0	-	1,925
Syria	0	0	-	57,355
Tajikistan	0	0	-	13,029
Timor-Leste	0	0	-	1,695
Tunisia	1	1	100·0%	50,067
Ukraine	0	0	-	519,761
Uzbekistan	0	0	-	90,959
Vanuatu	0	0	-	399
Vietnam	0	0	-	238,156
Yemen	0	0	-	69,006
Zambia	0	0	-	18,951
Program response rate in lower-MICs (15/17 countries with CR; 88·2% country response rate)	*54*	*72*	*75·0%*	-
Total Unmet Need in Lower-MICs	-	-	-	7,050,536
Low Income				
Afghanistan	1	1	100·0%	88,906
Benin	0	1	0·0%	-

Burkina Faso	0	0	-	19,241
Burundi	0	0	-	13,432
Central African Republic	0	0	-	6,831
Chad	0	0	-	16,436
Comoros	0	0	-	1,034
Democratic Republic of the Congo	0	0	-	82,818
Eritrea	0	0	-	5,386
Ethiopia	0	0	-	138,477
Gambia	0	0	-	2,607
Guinea	0	0	-	16,645
Guinea-Bissau	0	0	-	2,797
Haiti	0	0	-	23,896
Liberia	0	0	-	6,669
Madagascar	0	0	-	32,640
Malawi	0	0	-	25,374
Mali	0	0	-	17,278
Mozambique	0	0	-	41,012
Nepal	1	1	100·0%	63,134
Niger	0	0	-	23,462
North Korea	0	0	-	48,117
Rwanda	0	0	-	11,947
Senegal	0	0	-	20,843
Sierra Leone	0	0	-	9,247
Somalia	0	0	-	15,179
South Sudan	0	0	-	17,290
Tanzania	0	1	0·0%	-
Togo	0	0	-	9,988
Uganda	0	1	0·0%	-
Zimbabwe	0	0	-	21,766
Program response rate in LICs (2/5 countries with CR; 40·0% country response rate)	*2*	*5*	*40·0%*	-
Total Unmet Need in LICs	-	-	-	782,452
LMIC Program Response Rate (47/55 LMICs with CR; 85·5% country response rate)	*335*	*626*	*53·5%*	-
Total Unmet Need in all LMICs	-	-	-	14,766,930

LMICs, low- and middle-income countries; CR, cardiac rehabilitation

-not applicable/missing

*number of annual incident ischemic heart disease cases estimated in Global Burden of Disease study[30] minus national annual CR capacity, to reflect total number more CR spots needed per year. See Turk-Adawi et al. for a listing of these values by country.[24]

Supplementary Table 2. Accepted Cardiac Rehabilitation Indications by Country Income Classification and Funding Source, N=1082

	LMIC				HIC (n=747)	p*
	Private (n=103)	Public (n=115)	Hybrid (n=108)	Total† (n=326)‖		
Cardiac						
Myocardial Infarction/ Acute Coronary Syndrome	100 (97.1%)	78 (95.1%)	90 (90.68%)	268 (96.4%)	562 (97.9%)	0.52
PCI	94 (91.3%)	78 (95.1%)	91 (97.8%)	263 (94.6%)	554 (96.9%)	0.34
CABG	98 (95.1%)	78 (95.1%)	87 (93.5%)	263 (94.6%)	551 (96.3%)	0.83
Stable coronary artery disease, without a recent event or procedure	94 (91.3%)	72 (87.8%)	87 (93.5%)	253 (91.0%)	437 (76.4%)	0.06
Heart failure	88 (85.4%)	68 (82.9%)	87 (93.5%)	243 (87.4%)	511 (89.3%)	0.25
Valve procedure	80 (77.7%)	61 (74.4%)	71 (76.3%)	212 (76.3%)	522 (91.3%)	<0.01
Rhythm device	75 (72.8%)	60 (73.2%)	73 (78.5%)	208 (74.8%)	454 (79.4%)	0.16
Arrhythmias	76 (73.8%)	55 (67.1%)	75 (80.6%)	206 (74.1%)	358 (62.6%)	0.49
Cardiomyopathy	75 (72.8%)	56 (68.3%)	73 (78.5%)	204 (73.4%)	437 (76.4%)	0.27
Congenital heart disease	64 (62.1%)	46 (56.1%)	66 (71.0%)	176 (63.3%)	316 (55.2%)	0.39
Rheumatic heart disease	61 (59.2%)	53 (64.6%)	62 (66.7%)	176 (63.3%)	258 (45.1%)	<0.05
Ventricular assist devices	42 (40.8%)	38 (46.3%)	54 (58.1%)	134 (48.2%)	304 (53.1%)	0.24
Heart transplant	43 (41.7%)	28 (34.1%)	36 (38.7%)	107 (38.5%)	363 (63.5%)	<0.001
Non-cardiac						
High-risk / primary prevention	87 (84.5%) ǂ	50 (61.0%) ǂ	70 (75.3%)	207 (74.5%)†	283 (49.5%)	<0.01
Diabetes	85 (82.5%)	52 (63.4%)	66 (71.0%)	203 (73.0%)	215 (37.6%)	<0.001
Intermittent claudication/ peripheral vascular disease	68 (66.0%)	44 (53.7%)	59 (63.4%)	171 (61.5%)	250 (43.7%)	0.06
Chronic lung disease	66	34	56	156	183	<0.01

	(64.1%)	(41.5%)	(60.2%)	(56.1%)	(32.0%)	
Stroke / transient ischemic attack	40 (38.8%)	32 (39.0%)	31 (33.3%)	103 (37.1%)	150 (26.2%)	0.24
Cancer	35 (34.0%)	13 (15.9%)	24 (25.8%)	72 (25.9%)	91 (15.9%)	0.18

*Generalized Linear Mixed Models were used to test for significant differences in LMICs versus HICs.
†$p< 0.05$ for Generalized Linear Mixed Models testing for significant differences by most common funding source;
For pairwise comparisons ǂ=$p<0.01$
‖respondents did not provide information on funding source for CR in 9/335 surveys
CABG=Coronary artery bypass graft; HIC=high-income country; LMIC= low- and middle-income country; PCI=percutaneous coronary intervention.
Note: Due to missing data, percentages are computed where the denominator is the number of valid responses from responding programs.

Supplementary Table 3: Healthcare Professionals on Cardiac Rehabilitation Staff by Country Income Classification and Funding Source, N=1082

	LMIC				HIC (n=747)	p*
	Private (n=103)	Public (n=115)	Hybrid (n=108)	Total† (n=326)‖		
Cardiologist	91 (88.3%)	88 (92.6%)	87 (87.0%)	266 (89.3%)	453 (72.5%)	<0.001
Nurse	65 (65.0%)	79 (84.0%)	90 (90.0%)	234 (79.6%)	544 (91.7%)	<0.001
Physiotherapist	83 (81.4%)	73 (78.5%)	77 (76.2%)	233 (78.7%)	500 (79.9%)	0.60
Dietitian	82 (80.4%)	70 (75.3%)	67 (68.4%)	219 (74.7%)	520 (83.2%)	0.001
Administrative assistant / secretary	69 (68.3%)ǂ	56 (60.9%)	54 (55.1%)ǂ	179 (61.5%)†	417 (67.9%)	<0.05
Psychologist	50 (48.5%)	65 (69.9%)¶	53 (54.1%)	168 (57.1%)†	357 (58.0%)	0.69
Physiatrist / PM&R	42 (44.7%)	60 (63.2%)	51 (53.7%)	153 (53.9%)	235 (38.5%)	<0.001
Kinesiologist / Exercise specialist	61 (58.7%)	47 (50.5%)	45 (46.9%)	153 (52.2%)	310 (52.1%)	0.71
Other physician	43 (45.7%)	42 (46.7%)	32 (34.8%)	117 (42.4%)	215 (36.1%)	0.08
Sports medicine physician	42 (42.9%)	23 (25.3%)	38 (38.8%)	103 (36.1%)	80 (13.3%)	<0.001
Psychiatrist	33 (34.7%)	39 (42.9%)	27 (28.7%)	99 (35.4%)	107 (17.8%)	<0.001
Pharmacist	14 (14.6%)#	41 (46.1%)#	36 (37.9%)	91 (32.5%)††	275 (45.1%)	0.001
Social worker	16 (16.7%)#	39 (42.4%)#	25 (26.3%)	80 (28.3%)††	300 (48.8%)	<0.001
Community health worker	12 (12.8%)	24 (26.1%)	23 (24.5%)	59 (21.1%)	109 (18.0%)	0.28
Other	12 (21.8%)	18 (28.1%)	19 (25.7%)	49 (25.4%)	122 (39.0%)	0.001

Total # of program staff§	5.4 ± 2.5	6.3 ± 3.2	5.8 ± 2.8	5.8 ±2.8	5.9 ± 2.8	0.58

‖respondents did not provide information on funding source for CR in 9/335 surveys.
*Generalized Linear Mixed Models could not reliable be used to test for significant differences in LMICs versus HICs so Pearson's chi-square were computed.
† p< 0.05; †† p< 0.01; ††† p< 0.001 for Generalized Linear Mixed Models testing for significant differences by most common funding source;
For pairwise comparisons ǂ: one symbol=p<0.05; two symbols=p<0.01; 3 symbols=p<0.001
¶Significantly different from all funding sources (p<0.01).
HIC=high-income country; LMIC= low- and middle-income country
§frequency and percent of personnel on team, with full-time personnel counted as 1 and part-time personnel counted as 0.50.
Note: Due to missing data, percentages are computed where the denominator is the number of valid responses from responding programs.

Supplementary Table 4: Cardiac Rehabilitation Elements Delivered by Country Income Classification and Funding Source, N=1082

n (%)	LMIC				HIC (n=747)	p*
	Private (n=103)	Public (n=115)	Hybrid (n=108)	Total† (n=326)ǂ		
Core Components						
Initial Assessment	105 (99.1%)	96 (100.0%)	101 (99.0%)	305 (99.0%)	634 (98.8%)	0.91
Management of CV Risk Factors	103 (97.2%)	94 (97.9%)	101 (99.0%)	298 (98.0%)	627 (98.4%)	0.75
Patient Education	87 (96.7%)	87 (91.6%)	93 (96.9%)	267 (95.0%)	591 (97.7%)	0.39
End of program re-assessment	99 (93.4%)	86 (91.5%)	87 (87.9%)	272 (91.0%)	584 (91.8%)	0.74
Prescription and/or titration of medications	88 (82.2%)	89 (92.7%)	95 (93.1%)	272 (89.2%)	476 (74.6%)	0.13

Supervised Exercise Training	92 (86.0%)	71 (75.5%)	79 (78.2%)	242 (80.1%)	530 (82.8%)	0.83
Communication of assessment results to patients' primary care provider	88 (82.2%)◊	58 (61.1%)◊	78 (77.2%)	224 (73.9%)†	562 (89.1%)	<0.01
Stress Management	73 (68.9%)	66 (70.2%)	73 (72.3%)	212 (70.4%)	556 (87.0%)	<0.01
Tobacco cessation interventions sessions/classes	50 (47.6%)¶	72 (75.0%)	67 (67.0%)	189 (62.8%)†††	500 (78.2%)	0.001
Return-to-work counselling	58 (55.8%)	62 (66.0%)	62 (62.0%)	182 (61.1%)	431 (68.2%)	<0.05
<u>Other Elements</u>						
Heart rate measurement training / exercise intensity monitoring	104 (98.1%)	93 (96.9%)	101 (99.0%)	298 (98.0%)	587 (92.3%)	0.13

Individual consult with a physician	98 (92.5%)	89 (94.7%)	95 (94.1%)	282 (93.7%)	412 (64.4%)	<0.05
Assessment of Comorbidities	95 (91.3%)	86 (90.5%)	88 (88.0%)	269 (90.0%)	605 (94.7%)	0.10
Resistance Training	102 (95.3%)◊◊	76 (80.9%)◊◊	92 (90.2%)	270 (89.1%)†	585 (91.7%)	0.17
Nutrition Counseling	91 (85.0%)	85 (88.5%)	92 (90.2%)	268 (87.9%)	609 (95.2%)	<0.05
Exercise Prescription	98 (91.6%)	83 (87.4%)	85 (84.2%)	266 (87.8%)	566 (88.6%)	0.55
Physical Activity Counseling	96 (90.6%)	82 (86.3%)	86 (86.0%)	264 (87.7%)	582 (90.7%)	0.89
Exercise Stress Test	91 (85.8%)	83 (89.2%)	76 (76.8%)	250 (83.9%)	403 (63.5%)	<0.001
Follow-up post-program	87 (82.1%)	80 (84.2%)	75 (74.3%)	242 (80.1%)	418 (65.9%)	<0.01
Depression screening	79 (74.5%)	72 (75.0%)	83 (82.2%)	234 (77.2%)	579 (90.6%)	<0.01

Other Functional Capacity Test	82 (78.8%)	72 (76.6%)	72 (72.7%)	226 (76.1%)	506 (80.4%)	0.54
Psychological Counselling	67 (63.2%)◊	76 (80.0%)◊	78 (77.2%)	221 (73.2%)†	528 (82.5%)	0.09
Electronic patient charting	58 (63.7%)	48 (58.5%)	70 (70.7%)	176 (64.7%)	294 (59.3%)	0.86
Individual consult with a nurse	42 (40.8%)◊◊◊	70 (74.5%)◊◊◊	65 (65.7%)	177 (59.8%)††	536 (84.0%)	<0.001
Assessment of strength	66 (64.7%)	49 (52.1%)	57 (56.4%)	172 (57.9%)	273 (43.5%)	0.26
Alternative forms of exercise (e.g., yoga, dance)	44 (41.9%)	46 (48.9%)	50 (51.0%)	140 (47.1%)	213 (33.7%)	0.34
Women-only classes	17 (16.2%)	19 (20.4%)	18 (18.2%)	55 (18.3%)	55 (8.7%)	0.07
Other	20 (39.2%)	22 (33.8%)	24 (36.4%)	66 (36.3%)	46 (20.1%)	0.01
Total Elements (mean ± SD)§	18.2 ± 4.2	18.2 ± 4.9	18.3 ± 4.5	18.2 ± 4.5	18.9 ±3.8	0.18
Total core (/10)§	6.7 ± 2.6	6.7 ± 2.5	7.0 ± 2.4	7.3 ± 1.8	7.9 ± 1.7	<0.01

*Generalized Linear Mixed Models were used to test for significant differences in LMICs versus HICs.

† p< 0.05; †† p< 0.01; ††† p< 0.001 for Generalized Linear Mixed Models testing for significant differences by most common funding source;

‖respondents did not provide information on funding source for CR in 9/335 surveys

For pairwise comparisons ◊: one symbol=p<0.05; two symbols=p<0.01; 3 symbols=p<0.001

¶Significantly different from all funding sources (p<0.001).

CV=cardiovascular; HIC= high-income country; LMIC= low- and middle-income country; SD= standard deviation

§components offered in all models of CR counted as 1 and Components offered in some CR models counted as 0.50.

Note: Due to missing data, percentages are computed where the denominator is the number of valid responses from responding programs.