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Cardiac Rehabilitation Availability and Density around the Globe☆

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ABSTRACT

Background: Despite the epidemic of cardiovascular disease and the benefits of cardiac rehabilitation (CR), availability is known to be insufficient, although this is not quantified. This study ascertained CR availability, volumes and its drivers, and density.
Methods: A survey was administered to CR programs globally. Cardiac associations and local champions facilitated program identification. Factors associated with volumes were assessed using generalized linear mixed models, and compared by World Health Organization region. Density (i.e. annual ischemic heart disease [IHD] incidence estimate from Global Burden of Disease study divided by national CR capacity) was computed.
Findings: CR was available in 111/203 (54.7%) countries; data were collected in 93 (83.8% country response; N = 1082 surveys, 32.1% program response rate). Availability by region ranged from 80.7% of countries in Europe, to 17.0% in Africa ($p < .001$). There were 5753 programs globally that could serve 1,655,083 patients/year, despite an estimated 20,279,651 incident IHD cases globally/year. Volume was significantly greater where patients were systematically referred (odds ratio [OR] = 1.36, 95% confidence interval [CI] = 1.35–1.38) and programs offered alternative models (OR = 1.05, 95%CI = 1.04–1.06), and significantly lower with private (OR = .92, 95%CI = .91–.93) or public (OR = .83, 95%CI = .82–84) funding compared to hybrid sources.
Median capacity (i.e., number of patients a program *could* serve annually) was 246/program (Q25-Q75 = 150–390). The absolute density was one CR spot per 11 IHD cases in countries with CR, and 12 globally.
Interpretation: CR is available in only half of countries globally. Where offered, capacity is grossly insufficient, such that most patients will not derive the benefits associated with participation.

1. Introduction

Cardiovascular diseases (CVDs) are among the leading burdens of disease and disability globally [1,2]. In 2015, there were 422.7 million CVD cases around the world [2]. Secondary prevention is needed to mitigate the reduced quality and quantity of life in patients with this chronic disease. Cardiac rehabilitation (CR) is a cost-effective model of care shown to reduce cardiovascular mortality and morbidity by 20% [3,4].

Despite guidelines promoting referral to CR [5], and the clear association between availability and utilization [6], previous estimates suggested it is not available in over 60% of countries worldwide, and where it exists there is insufficient supply to meet growing need [7,8]. There has been one review of the literature globally [7], and another in low and middle-income countries [9], which has characterized CR availability, but to date there has been no primary study which has ascertained in which countries CR exists. Moreover, there have been a few studies which have characterized CR capacity at national or regional levels but not at a global level [10–12], and none have juxtaposed supply in relation to burden of diseases indicated for CR as per clinical practice guideline recommendations (i.e., density).

Accordingly, the aims of this study were to establish CR: (1) availability, (2a) volumes served and capacity, and (b) the factors associated with greater volume. Given this was the first study to establish CR volumes globally and no previous research has examined factors associated with program volumes to our knowledge, tests of association were exploratory. The study also aimed to establish CR: (3) density and (4) barriers to broader delivery. As applicable, these were described by program, country (including consideration of CR-indicated disease burden), World Health Organization (WHO) region, and globally. It was hypothesized there would be significant regional variation as well as in terms of disease burden in many of these parameters given the reviews outlined above [7,9]; however again, these analyses were exploratory given this is the first time CR has been scoped on a global scale.

2. Methods

2.1. Design & Procedure

This was a cross-sectional study. The study procedures were approved by York University's Office of Research Ethics (Toronto, Canada) and Mayo Clinic's Institutional Review Board (Rochester, United States). Participating CR centers provided informed consent electronically.

First, a list of all countries globally was compiled, by cross-referencing several key sources, including WHO [13,14]. Small islands

Research in context

Evidence before this study

Cardiac rehabilitation (CR) is an effective secondary prevention strategy for one of the leading burdens of disease and the leading cause of death globally, namely cardiovascular disease.

Reviews of the literature, however, suggested CR was only available in <40% of countries globally, and density, characterized in only several countries, was highly variable. Therefore, it is unknown how many patients can access these guideline-recommended services around the world, and where the greatest gaps exist.

Added value of this study

Cardiac rehabilitation availability around the world has been established for the first time. Based on primary data collected through this global survey, CR was shown to be available in 54·7% countries (median = 4 programs/country). The 5,753 programs in the world served a median of 157 (Q25–Q75 = 75–350) patients/year each. Programs that had systematic inpatient referral, hybrid funding sources and offered alternative models served significantly more patients, among other factors. Median national capacity in countries with CR was 1500 (Q25–75 = 300–7500) patients/year (120 across all countries globally). Where available, the density was one CR spot per 11 incident annual ischemic heart disease patients globally (lowest in Africa, greatest in Western Pacific).

Implications of all the available evidence

CR availability, capacity, and density are vastly insufficient to serve all patients in need.

Advocacy to develop greater capacity, particularly in Africa and South-East Asia, is needed to ensure all guideline-indicated patients derive the 20% mortality and re-hospitalization reductions associated with participation. Policies should promote greater public funding and support programs in delivering programming outside of clinical centers.

affiliated with larger countries were considered part of the larger country (e.g., Macau), and United Kingdom countries were considered separately given their disparate CR practices and policies. Two hundred and three countries were considered (Tables 1 and 2). Some of these countries are not categorized by WHO. These countries were allocated to the most applicable geographic region.

The incidence of CVD (i.e., practice guidelines for most of these diseases recommend CR) in each country [5], to represent the number of patients who would be indicated for CR in a given year (i.e., need), was sought. Estimates from the Global Burden of Disease (GBD) study were used [15], from 2016. Because the CVD grouping included rheumatic heart disease and stroke, to be conservative, ischemic heart disease (IHD) more specifically was selected, as it was the closest diagnostic option to CR-indicated conditions [16]. We created IHD incidence tertiles (Fig. 1). These data were used with the data on availability and capacity collected as per below to compute density.

With regard to availability, the following strategies and sources were used to confirm which countries offered any CR: (a) our previously-published review on global availability of CR [7], among other reviews [9], and (b) a search of MEDLINE, EMBASE, and Google Scholar for articles or abstracts on CR. For countries where no CR was in evidence, the authors: (a) searched the internet via Google using the term "cardiac rehabilitation" and country, (b) searched via Google for hospitals within these countries, which were then searched for CR programs, (c) used a snowball sampling strategy via the International Council of Cardiovascular Prevention and Rehabilitation (ICCPR) members and key informants in the field (including European Society of Cardiology national CVD prevention coordinators), as well as (d) attended international conferences of relevant societies to approach experts in the given countries (the latter 2 enabled us to identify programs that may not be advertised in English). Finally, before any country was designated as having no CR, international societies (e.g., International Society of Physical Medicine and Rehabilitation, African Heart Network) were contacted to ascertain whether there were any CR programs in countries where we lacked confirmation of availability.

In countries where CR existed, the total number of programs and contacts to reach those programs for data collection was then sought. First, available CR associations (or broader cardiac society leadership where not available) were contacted. Otherwise, "champions" were identified from the peer-reviewed, or gray literature/internet. Identified leaders were sent an e-mail requesting their collaboration. If there was no "champion" for a given country, the study team directly contacted CR programs that could be identified on the internet or through key informants. Based on the above, the total number of CR programs in each country was collated.

Finally, national champions were asked to circulate a link of the survey to all identified programs, or provide the study team with the email addresses of the programs to survey them directly. Data collection occurred from February 2016–July 2017 via online survey administered through REDCap.

2.2. Sample

The sample was comprised of all CR programs world-wide offering Phase II (i.e., post-acute care discharge) services (including residential programs [17]. Programs that offered: (1) initial assessment, (2) structured exercise, and (3) at least one other strategy to control CV risk factors, were included. All CR programs were contacted in countries with ≤350 programs; otherwise, a random non-stratified subsamples of 250 programs were generated electronically (using the simple random sample module SAS institute, Cary, NC) and were contacted.

2.3. Measures

This study focused on four main indicators, namely CR: (1) availability or existence (yes/no; ascertained as described above); (2) program volume, defined as the number of patients served by a program annually, (3) national capacity, or the median number of patients a program *could* serve annually (as both reported through the survey described below) among the responding programs in a given country, multiplied by the total number of programs in that country (ascertained from champion; Please note for countries where no surveys were completed, national capacity was computed by multiplying the number of programs by regional median program capacity); and (4) density, or national capacity (#3 above) per annual incident IHD case in a country (ascertained from GBD) [15]. The latter was ranked by country.

Development of the survey is described elsewhere [18]; it was pilot-tested in the Arab world and Canada. The final version was translated to Portuguese, Spanish, and traditional Chinese character [19]. The survey assessed annual program volume, capacity (both defined as per the above), and barriers to serving more patients (e.g., referral, human resources; rated on a 5-point Likert scale; and an open-ended item).

Because this was the first study to examine volume worldwide, potential factors associated with volume were selected based on expert opinion of the authors. Potential drivers of volume assessed included: (i) funding source, and the costs per patient, (ii) location of program and proximity to other programs; (iii) type and nature of institution where situated, (iv) healthcare professionals on the CR team, (v) wait times, (vi) number of patients served per session (as well as staff-to-

Table 1
Cardiac rehabilitation availability, volume, capacity, and density by country with any cardiac rehabilitation, N = 111.

WHO Region	Human Development Index*	IHD incidence†	Year 1st CR program	# CR programs in country	Median annual volume/program	Median annual capacity/program	National CR capacity‡	CR density§	CR density ranking‖
African (8 countries)									
Algeria	0.745	140,592	NA	1	NA	55	55	2556	72
Benin	0.485	11,973	NA	1	NA	55	55	218	57
Kenya	0.555	55,174	2010	3	20	50	150	368	62
Mauritius	0.513	3872	2013	1	60	60	60	65	46
Nigeria	0.527	223,994	2012	1	50	50	50	4480	73
South Africa	0.666	108,455	1989	23	50	90	2070	52	41
Tanzania	0.531	64,326	NA	1	NA	55	55	1170	69
Uganda	0.493	31,951	NA	1	NA	55	55	581	65
Mean ± SD	*0.564 ± 0.092*	*80,042 ± 74,459*	*2006 ± 11*	*4 ± 8*	*45 ± 15*	*59 ± 13*	*319 ± 708*	*1186 ± 1569*	*61 ± 12*
Median (Q25-Q75)	*0.529 (0.498–0.638)*	*59,750 (16968–132,558)*	*2011 (1994–2013)*	*1 (1–3)*	*50 (28–58)*	*55 (51–59)*	*55 (55–128)*	*474 (103–2210)*	*64 (49–71)*
Americas (28 countries)									
Argentina	0.827	122,357	1998	23	1500	2000	46,000	3	5
Aruba	NA	NA	NA	1	NA	200	200	NA	NA
Barbados	0.795	1240	1994	1	70	96	96	13	18
Bermuda	NA	197	2012	1	220	400	400	1	1
Brazil	0.754	529,062	1973	75	60	72	5400	98	51
Canada	0.920	91,030	1960	170	300	300	51,000	2	3
Chile	0.847	45,008	2009	10	30	200	2000	23	28
Colombia	0.727	75,245	1972	50	410	390	19,500	4	7
Costa Rica	0.776	8288	1985	6	45	120	720	12	17
Cuba	0.775	49,789	1973	8	145	180	1440	35	33
Curaçao	NA	NA	NA	2	120	200	400	NA	NA
Dominican Republic	0.722	193,919	2016	2	NA	200	400	485	64
Ecuador	0.739	27,046	1995	5	36	190	950	29	30
El Salvador	0.680	9129	NA	2	NA	200	400	23	28
Grenada	0.754	296	NA	1	NA	200	200	1	2
Guam	NA	311	NA	1	NA	200	200	2	3
Guatemala	0.640	13,671	2011	2	18	60	120	114	52
Honduras	0.625	10,939	2005	2	20	20	40	274	58
Jamaica	0.730	8026	2006	3	24	60	180	45	39
Mexico	0.762	161,348	1944	24	38	250	6000	27	29
Panama	0.788	5039	2006	1	38	80	80	63	44
Paraguay	0.693	14,892	2011	3	125	200	600	25	29
Peru	0.740	49,967	1992	10	80	250	2500	20	25
Puerto Rico	NA	15,286	NA	1	NA	200	200	76	47
Trinidad and Tobago	0.780	4759	NA	2	NA	200	400	12	17
United States of America	0.920	1,344,974	1970	2632	150	208	547,456	3	6
Uruguay	0.795	10,656	1970	12	120	200	2400	4	8
Venezuela	0.767	45,575	1974	9	103	163	1467	31	32
Mean ± SD	*0.763 ± 0.072*	*78,241 ± 233,742*	*1989 ± 20*	*109 ± 496*	*174 ± 320*	*251 ± 354*	*24,670 ± 103,253*	*55 ± 104*	*26 ± 19*
Median (Q25-Q75)	*0.762 (0.727–0.795)*	*10,656 (1152–47,682)*	*1994 (1973–2008)*	*3 (1–12)*	*80 (37–148)*	*200 (131–206)*	*500 (200–2475)*	*23 (4–49)*	*28 (7–41)*
Eastern Mediterranean (12 countries)									
Afghanistan	0.479	89,056	2014	1	100	150	150	594	5766
Bahrain	0.824	3842	1998	1	140	500	500	8	12
Egypt	0.691	369,488	2010	2	20	100	200	1847	70
Iran	0.774	235,157	1994	34	250	475	16,150	15	20
Kuwait	0.800	7648	NA	1	NA	246	246	31	32
Lebanon	0.763	27,633	2014	1	100	300	300	92	49
Morocco	0.647	156,088	2016	1	NA	246	246	635	67
Pakistan	0.550	622,146	2004	4	900	1500	6000	104	63
Qatar	0.856	7003	2013	1	157	192	192	37	34
Saudi Arabia	0.847	82,510	NA	1	NA	246	246	335	60
Tunisia	0.725	50,217	2010	1	90	150	150	335	59
United Arab Emirates	0.840	21,885	NA	1	NA	246	246	89	48
Mean ± SD	*0.733 ± 0.121*	*139,389 ± 187,985*	*2008 ± 8*	*4 ± 9*	*220 ± 283*	*363 ± 378*	*1677 ± 4573*	*369 ± 518*	*48 ± 20*
Median (Q25-Q75)	*0.763 (0.658–0.836)*	*66,363 (11,208–215,389)*	*2010 (2001–2014)*	*1 (1–2)*	*120 (93–227)*	*246 (161–431)*	*246 (194–450)*	*213 (32–549)*	*54 (33–65)*
Europe (46 countries)									
Austria	0.893	32,901	1962	26	750	200	5200	6	10
Belarus	0.796	88,874	1981	5	300	300	1500	59	44
Belgium	0.896	66,985	1977	48	275	300	14,400	5	9
Bosnia and Herzegovina	0.750	19,068	1959	1	800	2000	2000	10	15
Bulgaria	0.794	55,871	1958	1	2200	3000	3000	19	24
Croatia	0.827	26,066	1957	3	940	940	2820	9	14

Table 1 (*continued*)

WHO Region	Human Development Index*	IHD incidence†	Year 1st CR program	# CR programs in country	Median annual volume/program	Median annual capacity/program	National CR capacity‡	CR density§	CR density ranking‖
Cyprus	0.856	2665	NA	1	NA	NA	NA	NA	11
Czech Republic	0.878	66,012	1993	15	65	200	3000	22	27
Denmark	0.925	23,455	1990	35	200	250	8750	3	6
England	0.909	318,284	1978	266	490	500	133,000	2	4
Estonia	0.865	10,938	1994	2	150	150	300	37	35
Finland	0.89	25,677	1978	25	55	98	2450	11	16
France	0.897	259,251	1972	130	475	485	63,050	4	8
FYR of Republic of Northern Macedonia	0.748S	8285	NA	1	NA	375	375	22	27
Georgia	0.769	16,488	1994	17	180	600	10,200	2	4
Germany	0.926	385,474	1950	120	800	825	99,000	4	8
Greece	0.866	61,036	1993	4	20	100	400	153	54
Hungary	0.836	69,698	1970	33	440	580	19,140	4	8
Iceland	0.921	1570	1983	4	168	185	740	2	4
Ireland	0.923	16,000	1985	37	256	300	11,100	1	6
Israel	0.899	23,152	1964	22	1000	1000	22,000	1	2
Italy	0.887	359,226	1974	221	350	355	78,455	5	9
Kazakhstan	0.794	57,125	NA	1	NA	375	375	152	53
Kyrgyz Republic	0.664	11,398	NA	1	NA	375	375	NA	31
Latvia	0.830	14,743	1997	2	150	400	800	18	23
Lithuania	0.848	23,421	1977	25	950	1000	25,000	1	2
Luxembourg	0.898	1683	NA	4	NA	375	1500	1	2
Malta	0.856	1958	2012	1	300	900	900	2	4
Moldova	0.699	21,376	2016	1	200	400	400	53	42
Montenegro	0.807	3049	NA	1	NA	375	375	8	13
Netherlands	0.924	88,550	1974	90	555	450	40,500	2	4
Northern Ireland	NA	8811	1980	13	255	215	2795	3	6
Norway	0.949	15,197	NA	35	NA	375	13,125	41	37
Poland	0.855	237,460	1973	56	350	375	21,000	11	16
Portugal	0.843	35,884	1988	23	75	100	2300	16	21
Romania	0.802	126,835	1978	3	1400	2500	7500	17	22
Russia	0.804	1,223,642	2010	3	400	500	1500	816	68
Scotland	NA	30,185	1985	69	356	296	20,424	1	2
Serbia	0.776	40,265	1968	2	1345	1570	3140	13	19
Slovak Republic	0.845	29,436	2015	7	50	200	1400	21	26
Slovenia	0.890	11,135	1995	2	100	150	300	37	35
Spain	0.884	175,537	1993	87	120	120	10,440	17	22
Sweden	0.913	50,475	NA	69	150	150	10,350	5	9
Switzerland	0.939	29,546	1997	51	255	255	13,005	2	4
Turkey	0.767	337,617	2010	10	100	350	3500	97	50
Wales	NA	15,432	1986	17	490	375	6375	2	4
Mean ± SD	*0.852 ± 0.065*	*98,429 ± 198,290*	*1984 ± 17*	*35 ± 55*	*466 ± 463*	*550 ± 604*	*14,536 ± 27,142*	*38 ± 122*	*19 ± 17*
Median (Q25-Q75)	*0.861 (0.804–0.898)*	*29,491 (15,084-74,411)*	*1984 (1974–1994)*	*14 (2–40)*	*300 (150–750)*	*375 (211–520)*	*3070 (875–13,444)*	*9(2–22)*	*14 (6–27)*
South-East Asia (6 countries)									
Bangladesh	0.579	409,210	NA	1	160	200	200	2046	71
India	0.624	3,313,674	1997	23	200	400	9200	360	61
Indonesia	0.689	66,676	1985	13	98	100	1300	51	40
Nepal	0.558	66,134	2008	1	2000	3000	3000	22	27
Sri Lanka	0.766	66,927	2012	4	114	105	420	159	55
Thailand	0.740	199,828	NA	5	NA	200	1000	200	56
Mean ± SD	*0.659 ± 0.086*	*687,075 ± 1,293,730*	*2001 ± 12*	*8 ± 9*	*514 ± 831*	*668 ± 1148*	*2520 ± 3419*	*473 ± 780*	*52 ± 16*
Median (Q25-Q75)	*0.656 (0.573–0.747)*	*133,378 (66541–1,135,326)*	*2003 (1998–2011)*	*5 (1–16)*	*160 (106–1100)*	*200 (104–1050)*	*1150 (365–4550)*	*179 (44–782)*	*56 (37–64)*
Western Pacific (11 countries)									
Australia	0.939	80,169	1970	314	200	200	62,800	1	2
Brunei	0.865	471	2004	2	55	80	160	3	6
China	0.738	3,104,203	1984	216	300	325	70,200	44	38
Japan	0.903	501,740	1990	325	150	300	97,500	5	9
Malaysia	0.789	86,224	2007	6	300	250	1500	58	43
Mongolia	0.735	5241	2013	1	NA	250	250	21	25
New Zealand	0.915	10,110	1968	43	200	146	6278	2	4
Philippines	0.682	217,107	1975	10	105	560	5600	39	36
Singapore	0.925	14,299	1979	7	260	438	3066	5	9
South Korea	0.901	94,661	2009	17	200	250	4250	22	27
Taiwan	NA	43,795	1978	35	70	180	6300	7	11
Mean ± SD	*0.839 ± 0.094*	*378,002 ± 873,254*	*1989 ± 16*	*89 ± 124*	*181 ± 80*	*271 ± 135*	*23,446 ± 35,315*	*19 ± 20*	*19 ± 15*

(*continued on next page*)

Table 1 (*continued*)

WHO Region	Human Development Index*	IHD incidence†	Year 1st CR program	# CR programs in country	Median annual volume/program	Median annual capacity/program	National CR capacity‡	CR density§	CR density ranking‖
Median (Q25-Q75)	*0.883 (0.737–0.918)*	*80,169 (10110–217,107)*	*1984 (1975–2007)*	*17 (6–216)*	*200 (96–263)*	*250 (180–250)*	*5600 (1500–4588)*	*7(3–6)*	*11 (6–36)*
Global Mean ± SD	***0.782 ± 0.117***	***164,764 ± 464,692***	***1990 ± 18***	***52 ± 254***	***324 ± 426***	***398 ± 534***	***14,911 ± 55,757***	***181 ± 568***	***27 ± 21***
Global Median (Q25-Q75)	***0.795 (0.729–0.881)***	***40,265 (11267–101,558)***	***1992 (1975–2009)***	***4 (1–25)***	***157 (75–350)***	***246 (150–390)***	***1500 (300–7500)***	***21(4–83)***	***25 (8–47)***

*Human Development Index was obtained from United Nations Development Program [31].
†Incidence of IHD was obtained from Global Burden of Disease study [15].
‡National CR capacity calculated using median number of patients program could serve per year (from survey) multiplied by the number of programs in the country (ascertained from national champions). Value represents the number of patients who could receive CR in a year (i.e., CR spots). For country without a response, national capacity estimated based on regional median program capacity multiplied by number of programs in that country.
§CR density refers to the number of incident IHD cases per year per CR spot (i.e., national CR capacity).
‖Ranking based on density, or ratio of need (i.e., IHD incidence) to supply (i.e., national CR capacity). Lower numbers reflect more CR spots per IHD patient (i.e., of 86 countries where CR and sufficient information are available such that 1 represents the most spots per IHD patient and 86 is the least spots per patient).
Acronyms: IHD, ischemic heart diseases; CR cardiac rehabilitation; NA, not available; SD, standard deviation; WHO, World Health Organization.

patient ratio and case-mix), (vii) core components and other elements delivered, (viii) dose of CR; (ix) equipment/resources available, and whether patients are monitored during exercise using telemetry, and (x) whether the program offers CR in alternative settings (e.g., home-based, or community-based).

2.4. Statistical Analyses

IBM SPSS version 24 was used for analysis [20], and $p < .05$ considered statistically significant where exploratory inferential statistics were performed. Descriptive statistics (e.g., frequency with percentage or median with quartiles, as appropriate) were used to characterize CR availability, volumes, capacity, and density, as well as the survey items related to access and barriers. These were described by country, WHO region, and/or IHD incidence tertiles [15].

Herein, data from programs nested within countries is presented. Therefore, clustering of program-level data within countries was taken into consideration in the inferential tests outlined below.

Differences in the CR availability indicators above (dependent variables; i.e., programs per country, program volumes, annual capacity, density) were tested by region and IHD incidence tertile (independent variables) in an exploratory manner via generalized linear mixed models (GLMM), to account for clustering of programs, where country was the random effect. The models were fitted via the Poisson distribution log link function, because the dependent variables were positively skewed. Barriers to broader delivery were tested in the same manner, by WHO region only. Similarly, differences in CR availability (yes/no; dependent variable) were also tested by region via GLMM, but using a binomial distribution with logit link function. For each analysis, the distribution of the residuals was reviewed to consider the model performance.

Finally, potential drivers of volumes were explored using a two-step approach: (a) first in a bivariate manner (using t-tests, analysis of variance or Pearson's correlation as applicable); and where statistically significant, (b) using GLMM, where volume was the dependent variable, and country served as a higher-order variable. A two-step approach was used because multiple potential factors associated with volume were considered as this was exploratory, so by running fewer multivariate models this would minimize type 1 error.

Using "country" as a random effect in the drivers of volume model, the obtained ICC was = (Random effect)/(Random effect + Residual effect)ICC = 1.04/(1.04 + 1.00) = 0.51, i.e. 51.1% of variance in this model is explained by using "country" as random effect. Because volume was positively skewed, the model was fitted via the Poisson distribution log link function.

3. Results

CR was identified to be available in 111/203 countries (54.7%; Table 1). Data were collected in 93 (83.8% country response rate) countries (see [19]), from which 1082 (32.1% program response; rate by country reported elsewhere) surveys were initiated [19]. A random sub-sample of programs was surveyed in the United States only, and a non-random convenience sub-sample (due to champion preference) in Japan, Scotland (1–2 programs per health board/region) and Austria.

3.1. Availability

There were 92 countries in the world that lack any CR (Table 2), of which 12 (6.1% of the 196 countries with 2016 incidence estimates) were estimated to have high IHD incidence (Fig. 1) [15].

Availability of any CR in countries by WHO region was: 46/57 (80.7%) countries in Europe, 28/40 (70.0%) countries in Americas, 6/11 (54.5%) countries in South East Asia, 12/22 (54.5%) countries in the Eastern Mediterranean Region (EMR), 11/26 (42.7%) countries in the Western Pacific, and 8/47 (17.0%) countries in the African region ($p < .001$).

The first CR program opened in 1944 in Mexico (Table 1). Soon after, programs opened in Eastern Europe (Germany [1950], Croatia [1957], and Bulgaria [1958]). More than half of the participating programs ($n = 565$; 60.5%), in 30 countries ($N = 89$; 34.1%), opened since 2000.

There were 5753 CR programs in the world (counting all programs in the United States).

The median number of programs per country was one; this ranged from a low of zero in the African and Western Pacific regions, to a high of four in Europe (shown in countries with CR in Table 1 and Fig. 2; $p < .001$). There was a median of zero programs/country in countries with the lowest IHD incidence, one program in countries with moderate IHD incidence, and six programs in countries with the highest IHD incidence ($p < .001$; again, tertiles shown in Fig. 1).

3.2. Volume and Its Drivers

Median program volumes ranged from a low around 20 patients/program in several countries (e.g., Guatemala, Honduras, Kenya, Egypt, and Greece), to over 1000 in others (e.g., Scotland, Romania, Serbia, Argentina, Bulgaria, Nepal; Table 1) per year. They were lowest in Africa, and highest in Europe ($p < .001$). The median program volume was 35 patients in countries with the lowest IHD incidence, 200 patients in countries with moderate IHD incidence, and 250 patients in countries with the highest IHD incidence ($p < .001$).

In multivariate models, program volume was statistically significantly greater where there were other programs in close proximity,

Table 2
Estimated annual ischemic heart disease incidence (2016) in countries without cardiac rehabilitation and globally, N = 92.

Country	WHO region	Human Development Index*	IHD incidence†	IHD incidence/100,000†
Ukraine	Europe	0.743	519,761	1139
Vietnam	Western Pacific	0.683	238,156	253
Ethiopia	Africa	0.448	138,477	135
Iraq	Eastern Mediterranean	0.649	117,130	297
Sudan	Eastern Mediterranean	0.490	111,063	282
Myanmar	South-East Asia	0.556	108,283	199
Uzbekistan	Europe	0.701	90,959	299
Democratic Republic of the Congo	Africa	0.592	82,818	104
Yemen	Eastern Mediterranean	0.485	69,006	245
Syria	Eastern Mediterranean	0.536	57,355	315
North Korea	South-East Asia	NA	48,117	182
Mozambique	Africa	0.418	41,012	142
Ghana	Africa	0.579	36,001	127
Madagascar	Africa	0.512	32,640	131
Cote d'Ivoire	Africa	0.474	31,106	135
Azerbaijan	Europe	0.759	28,593	291
Cameroon	Africa	0.518	25,761	107
Malawi	Africa	0.476	25,374	141
Angola	Africa	0.533	24,579	95
Haiti	Americas	0.493	23,896	215
Niger	Africa	0.353	23,462	117
Cambodia	Western Pacific	0.563	22,764	143
Jordan	Eastern Mediterranean	0.741	22,639	293
Zimbabwe	Africa	0.516	21,766	136
Senegal	Africa	0.494	20,843	135
Libya	Eastern Mediterranean	0.716	20,254	329
Bolivia	Americas	0.674	19,423	175
Burkina Faso	Africa	0.402	19,241	103
Zambia	Africa	0.579	18,951	114
South Sudan	Africa	0.418	17,290	127
Mali	Africa	0.442	17,278	96
Guinea	Africa	0.414	16,645	129
Chad	Africa	0.396	16,436	114
Somalia	Eastern Mediterranean	NA	15,179	146
Burundi	Africa	0.404	13,432	116
Tajikistan	Europe	0.627	13,029	152
Oman	Eastern Mediterranean	0.796	12,703	270
Rwanda	Africa	0.498	11,947	99
Armenia	Europe	0.743	11,125	366
Papua New Guinea	Western Pacific	0.516	11,091	141
Laos	Western Pacific	NA	10,390	144
Togo	Africa	0.487	9988	135
Albania	Europe	0.764	9490	328
Turkmenistan	Europe	0.691	9388	171
Sierra Leone	Africa	0.420	9247	140
Nicaragua	Americas	0.645	7341	119
Central African Republic	Africa	0.352	6831	136
Liberia	Africa	NA	6669	144
Congo	Africa	0.592	5921	126
Mauritania	Africa	0.513	5612	138
Eritrea	Africa	0.420	5386	101
Botswana	Africa	0.698	3569	155
Namibia	Africa	0.640	3412	136
Lesotho	Africa	0.497	2997	140
Guinea-Bissau	Africa	0.424	2797	147
Gambia	Africa	0.452	2607	127
Gabon	Africa	0.6971	2272	129
Swaziland	Africa	0.541	1925	144
Guyana	Americas	0.638	1814	237
Timor-Leste	South-East Asia	0.605	1695	146
Fiji	Western Pacific	0.736	1631	189
Suriname	Americas	0.725	1468	269
Djibouti	Eastern Mediterranean	0.473	1407	145
Bhutan	South-East Asia	0.607	1319	165
Equatorial Guinea	Africa	0.592	1105	132
Bahamas	Americas	0.792	1063	268
Comoros	Africa	0.497	1034	133
Cape Verde	Africa	NA	965	176
Solomon Islands	Western Pacific	0.515	753	126
Maldives	South-East Asia	0.701	625	172
Belize	Americas	0.706	596	159
Saint Lucia	Americas	0.735	525	288
Vanuatu	Western Pacific	0.597	399	144
Andorra	Europe	0.858	336	425

(continued on next page)

Table 2 (*continued*)

Country	WHO region	Human Development Index*	IHD incidence†	IHD incidence/100,000†
Samoa	Western Pacific	0.704	299	151
Saint Vincent and Grenadines	Americas	0.722	296	268
Sao Tome and Principe	Africa	0.574	263	133
Seychelles	Africa	0.782	249	257
Antigua and Barbuda	Americas	0.786	235	256
Dominica	Americas	0.726	209	282
Tonga	Western Pacific	0.721	168	156
Kiribati	Western Pacific	0.588	162	143
Federated States of Micronesia	Western Pacific	0.638	147	142
Greenland	Europe	NA	99	200
Marshall Islands	Western Pacific	NA	98	132
Kosovo	Europe	NA	NA	NA
Monaco	Europe	NA	NA	NA
Nauru	Western Pacific	NA	NA	NA
Palau	Western Pacific	0.788	NA	NA
Palestine	Eastern Mediterranean	0.684	NA	NA
Saint Kitts and Nevis	Americas	0.765	NA	NA
Tuvalu	Western Pacific	NA	NA	NA

*Human Development Index was obtained from United Nations Development Program [31].
†Incidence of IHD was obtained from Global Burden of Disease study [15].
Acronyms: FYR, Former Yugoslav Republic; IHD, ischemic heart diseases; NA, not available; WHO, World Health Organization.

programs were located in hospitals offering advanced cardiac procedures, there was systematic referral in the associated hospital, programs were funded by a combination of private and public sources, programs offered alternative CR models/settings (including residential programs), there was a cardiologist on the CR team, and patients were offered an individual consult with a physician during the program, programs served patients at high-risk of cardiovascular disease (primary prevention), the number of patients served per session and per staff member was larger, and programs offered smoking cessation services. Volume was statistically significantly lower where patients had longer wait times, and programs offered more core components (Table 3).

Globally, there was ≥1 program that offered home-based CR in 38 [40.9%] of the 93 countries that offer CR. There were 152 (12.4%) programs offering home-based programs, where an estimated 21.4 ± 22.8% of the programs' total patients were served each year (median of 10.0%; Q1-Q3: 5.0–30.0%). Only 108 (10.0%) programs offered community-based (in 26/93 [28.0%] countries there was ≥1 program that offered community-based), where 38.1 ± 32.3% of their patients were served (median of 27.5%; Q1–Q3: 10.0–61.3%). Eighty-nine (8.1%) programs offered a hybrid model (i.e., supervised sessions transitioning to other setting). Eighty-eight (57.9%) programs offering home-based models reported their program had sufficient home-based capacity to meet patient demand for that model, while the rest of the programs (n = 64; 42.1%) reported capacity constraints, such as insufficient human resources (n = 42, 65.6%) and lack of funding (n = 31, 48.4%).

3.3. Capacity

Annual program capacity was lowest in Africa, and highest in Europe ($p < .01$; Table 1). The median program capacity was 200 patients in countries with the lowest IHD incidence, as well as in countries with

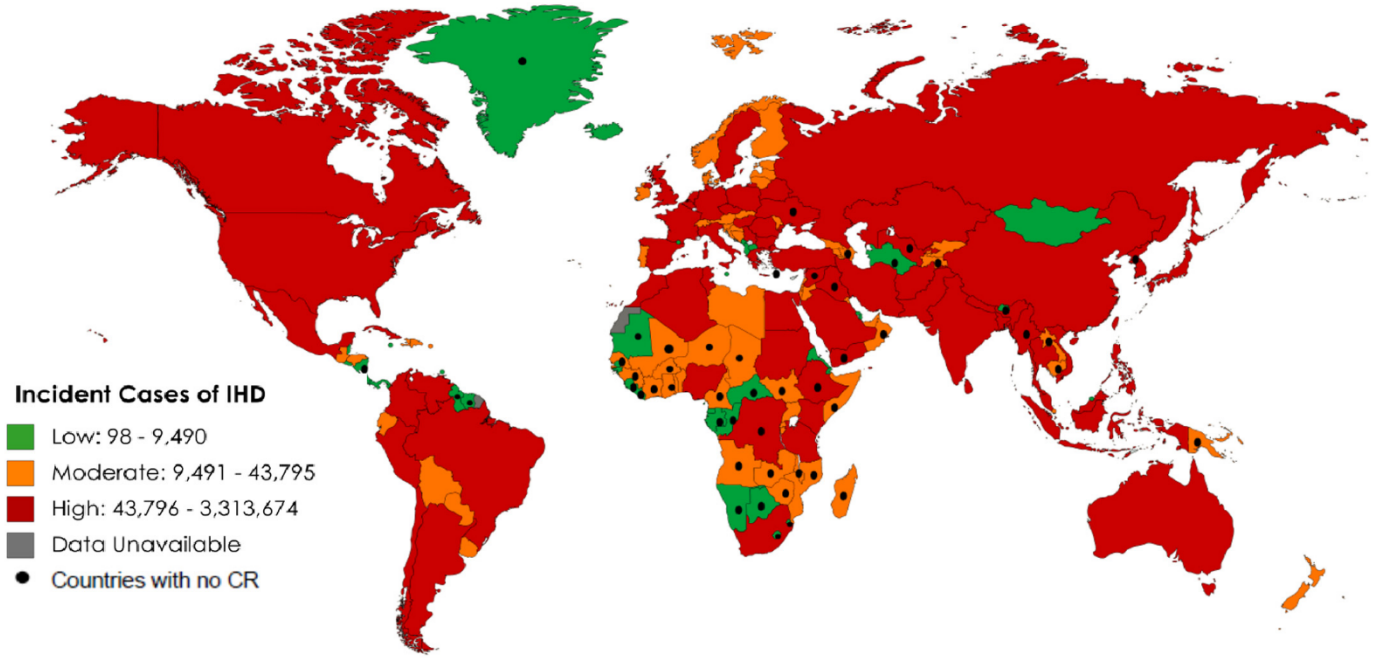

Fig. 1. Global availability of cardiac rehabilitation, by age-standardized ischemic heart disease incidence tertile (2016). Source of incidence estimates: Global Burden of Disease Study [15]
IHD, ischemic heart disease; CR, cardiac rehabilitation.

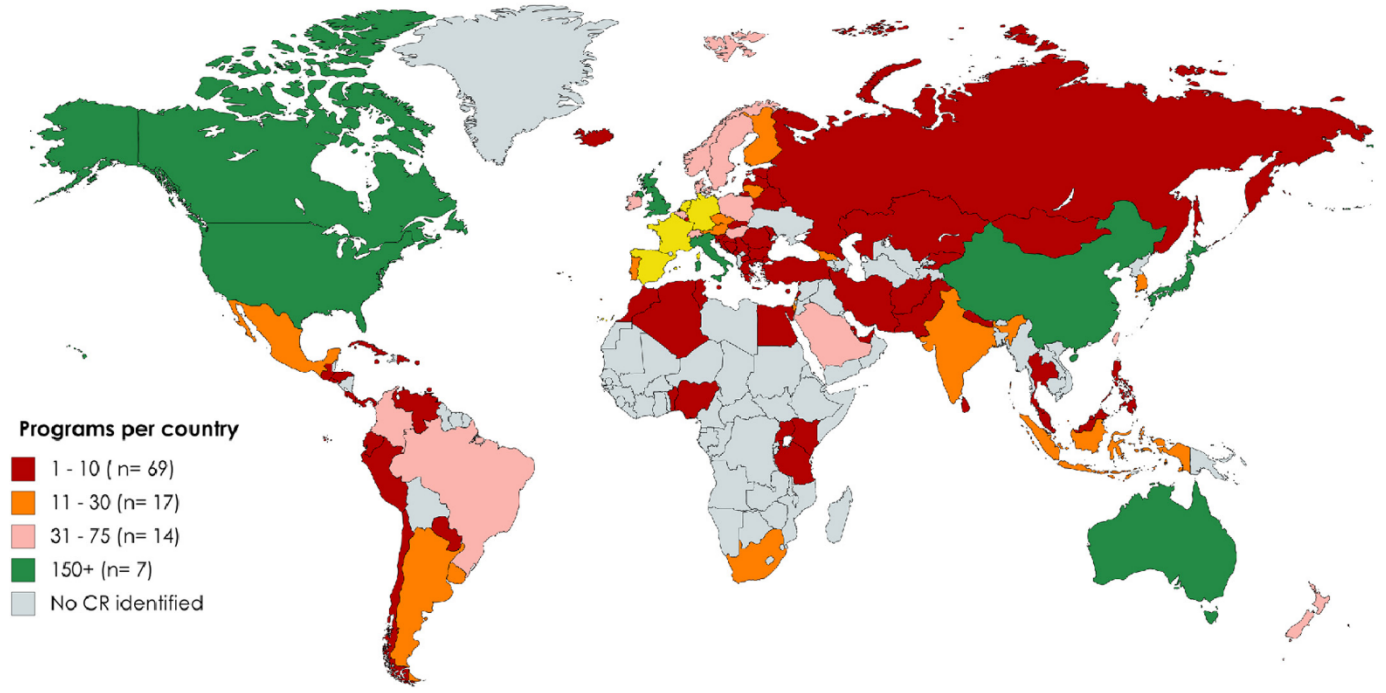

Fig. 2. Total number of cardiac rehabilitation programs per country.

moderate IHD incidence, and 250 patients in countries with the highest IHD incidence. On average, program volumes were 82.8% of annual capacity.

Median annual national capacity was lowest in Africa and greatest in the Western Pacific followed by Europe (Table 1; $p < .001$). Median annual national capacity across all countries (i.e., considering zero for countries without CR) was zero for Africa, and the Western Pacific, 150 for EMR, 200 for South-East Asia, 200 for the Americas, and 2300 for Europe. Median national capacity was zero in countries with the lowest IHD incidence, zero in countries with moderate IHD incidence, and 400 in countries with the highest IHD incidence. Global capacity was 1,655,083 patients/year.

3.4. CR Density

North America, Australia, Japan, and a few countries in Western Europe had the fewest estimated incident IHD patients/program/year (197–2089 patients/program; Fig. 3).

CR density in countries with CR ranged from one CR spot per 0.5 incident IHD patient/year (there were three countries with a density less than one suggesting they could treat other guideline-indicated patients as well) in Bermuda to per 4480 patients in Nigeria (Table 1; which should not be over-interpreted as there was only one program in these two countries) [15]. IHD incidence in countries without CR is shown in Table 2, reflecting unmet CR need.

Density was poorest in Africa, and best in the Western Pacific (in countries with CR; Table 1; $p < .001$). Median annual national density including countries without CR was zero spots in Africa and the Western Pacific, one spot per 22 patients in South-East Asia, per 11 in the EMR, per five in Europe, and per four patients in the Americas.

3.5. Causes

Globally, lack of financial resources was the most strongly rated barrier to greater CR delivery, followed by lack of patient referral, then lack of human resources (Table 4). Lack of patient referral was rated as a statistically significantly greater barrier in the Americas and EMR than in Europe ($p < .05$ for each); no other differences were observed.

Finally, respondents were asked to list any other barriers, and these included: lack of transport, parking and distance for patients ($n = 95$, 30.8%), lack of reimbursement/coverage ($n = 47$, 15.3%), lack of patient knowledge or awareness ($n = 36$, 11.7%), patient return-to-work ($n = 28$, 9.1%), lack physician and healthcare administrator awareness ($n = 26$, 8.4%), perceived lack of patient motivation ($n = 3.9\%$), lack of program capacity ($n = 9$, 2.9%), and lack of trained personnel ($n = 7$, 2.3%).

4. Discussion

Despite the WHO Global Action Plan 2013–2020 for the prevention of non-communicable diseases recognizing the important role of CR in stemming the epidemic of CVD [21], for the first time, it has been established that CR is available in only half of the countries of the world. This is disheartening given that CVD is the leading cause of death globally [1], and participation is associated with 20% lower cardiovascular mortality [4]. Almost 19 million more CR spots would be needed to treat all incident IHD patients/year [15], and this does not include heart failure [22], among other patient groups indicated for CR [5]. Clearly, millions of patient deaths could be prevented around the world if CR programs were implemented [23,24], with disproportionately more benefit to be gained in some regions than others. Notably, the Africa region, where CVD mortality is expected to increase more than any other WHO region in the next decade had the lowest CR availability [25], capacity and density (with 1,345,695 more spots needed to treat all incident IHD cases annually). In the countries with CR, one-third has only one program, and another half has ≤5 programs.

Where there is the most pressing need (i.e., high IHD incidence and low resources, hence high mortality rates and lack of access to cardiac care), CR is often non-existent. For example, Ukraine, with the highest estimated IHD incidence of 519,761 [15], does not have any CR. Similarly, Vietnam and Ethiopia do not have CR, despite having 238,156 and 138,477 incident IHD cases annually, respectively [15]. Bangladesh, with its estimated 409,210 incident IHD cases has only one program; the same situation exists in Nigeria, with its estimated 223,994 incident IHD cases.

The number of patients served per program was shown for the first time (only previously reported in South America where, consistent with

Table 3
Drivers of annual cardiac rehabilitation program volume.

Factor	n (%)/mean ± SD	Annual program volume (mean ± SD)	Univariate test Statistic	Univariate p	GLMM OR°	95% CI
CR Location			F = 0.45	0.636		
Urban	774 (71.6%)	503.9 ± 928.0			–	–
Suburban	155 (14.3%)	509.9 ± 814.5			–	–
Rural	134 (12.4%)	410.7 ± 550.5			–	–
Other CR program within 20 km			t = 2.57	0.010		
Yes	495 (45.7%)	574.7 ± 1104.5			1.20	1.19–1.21
No	516 (47.7%)	420.7 ± 629.0			–	
Located in referral center/tertiary facility/academic hospital			t = 1.40	0.162		
Yes	484 (44.7%)	549.3 ± 1001.1		–	–	–
No	566 (52.3%)	460.1 ± 809.4				
Located in hospital offering coronary bypass surgery			t = 2.68	0.008		
Yes	441 (40.8%)	601.9 ± 1138.5			1.25	1.24–1.26
No	612 (56.6%)	422.7 ± 647.6			–	
Systematic referral in associated hospital			t = 2.92	0.017	1.36	1.35–1.38
Yes	647 (59.8%)	586.7 ± 856.1			–	
No	182 (16.8%)	439.3 ± 1088.1				
CR funding source*			F = 12.30	<0.001		
Hybrid	268 (24.8%)	695.8 ± 1276.1			–	
Public	592 (54.7%)	455.0 ± 619.8			0.83	0.82–0.84
Private	202 (18.7%)	344.4 ± 840.7			0.92	0.91–0.93
Any patient funding						
Yes	396 (36.6%)	535.9 ± 1188.5	t = 0.87	0.387	–	–
No	668 (61.7%)	472.4 ± 631.4				
Estimated program cost to treat one patient (PPP 2016 USD)	$1560.2 ± 1686.3	–	r = −0.01	0.817	–	–
Program offers alternative CR models/settings			t = −2.58	0.010		
Yes	285 (26.3%)	584.5 ± 720.7			1.05	1.04–1.06
No	630 (58.2%)	478.6 ± 1017.9			–	
Residential program			t = 2.16	0.0.038		
Yes	24 (2.2%)	1880.3 ± 2364.5			2.41	0.39–15.12
No	1058 (97.8%)	618.3 ± 716.2			–	
Total number staff on CR team†	5.0 ± 3.2	–	r = 0.03	0.375	–	–
Cardiologist on the CR team			t = 3.24	0.001		
Yes	721 (66.6%)	543.8 ± 1004.5			1.16	1.15–1.18
No	205 (18.9%)	359.5 ± 503.7			–	
Individual consult with physician			t = 2.18	0.029		
Yes	697 (64.4%)	534.5 ± 1017.7			1.33	1.31–1.36
No	298 (22.9%)	408.8 ± 529.9			–	
Wait times from inpatient discharge to initiate CR (weeks)	3.5 ± 3.6	–	r = − 0.86	0.015	0.91	0.90–0.92
Program serves heart failure, transplant and/or VAD patients (i.e., higher-risk/case-mix)			t = 1.49	0.129	-	-
Yes	793 (73.3%)	521.0 ± 911.3				
No	60 (5.5%)	324.4 ± 491.2				
Program serves patients at high-risk of cardiovascular disease (primary prevention)			t = 2.77	0.006		
Yes	493 (45.6%)	579.3 ± 1034.7			1.32	1.30–1.33
No	360 (33.3%)	405.4 ± 616.5			–	
Number of patients served per session	9.1 ± 5.9	–	r = 0.31	<0.001	3.04	2.98–3.11
Number of patients served per 1 staff	4.8 ± 8.0	–	r = −0.08	0.044	0.99	0.98–0.99
Supervised dose (hours) ‡	35.2 ± 50.9	–	r = 0.03	0.403	–	–
Number of core components offered§	7.5 ± 1.7	–	r = −0.09	0.010	0.93	0.94–0.95
Risk factor management			t = 1.48	0.140		
Yes	928 (85.8%)	511.1 ± 931.7			–	–
No	17 (1.6%)	113.0 ± 144.1				
Exercise training			t = 0.036	0.971		
Yes	898 (83.0%)	502.6 ± 939.7			–	–
No	54 (5.0%)	508.2 ± 536.4				
Patient Education			t = 1.19	0.236		
Yes	860 (79.5%)	518.5 ± 946.4			–	–
No	28 (2.2%)	267.0 ± 315.6				
Psychological counseling/stress management			t = 1.89	0.060		
Yes	651 (60.2%)	521.9 ± 956.3			–	–
No	297 (27.4%)	303.2 ± 417.6				
Smoking cessation services			t = 1.91	0.023		
Yes	692 (64.0%)	540.7 ± 991.8			1.07	1.05–1.08
No	252 (23.3%)	394.0 ± 681.8			–	
Women-only classes			t = −2.32	0.023		
Yes	110 (10.1%)	868.6 ± 1774.6			1.01	1.00–1.03
No	820 (75.8%)	446.4 ± 706.3			–	
Total equipment‖	9.3 ± 4.4	–	r = 0.05	0.152	–	–
Telemetry during exercise			t = −0.80	0.421		
Yes	397 (36.7%)	508.7 ± 982.6			–	–
No	513 (47.4%)	510.5 ± 773.3				

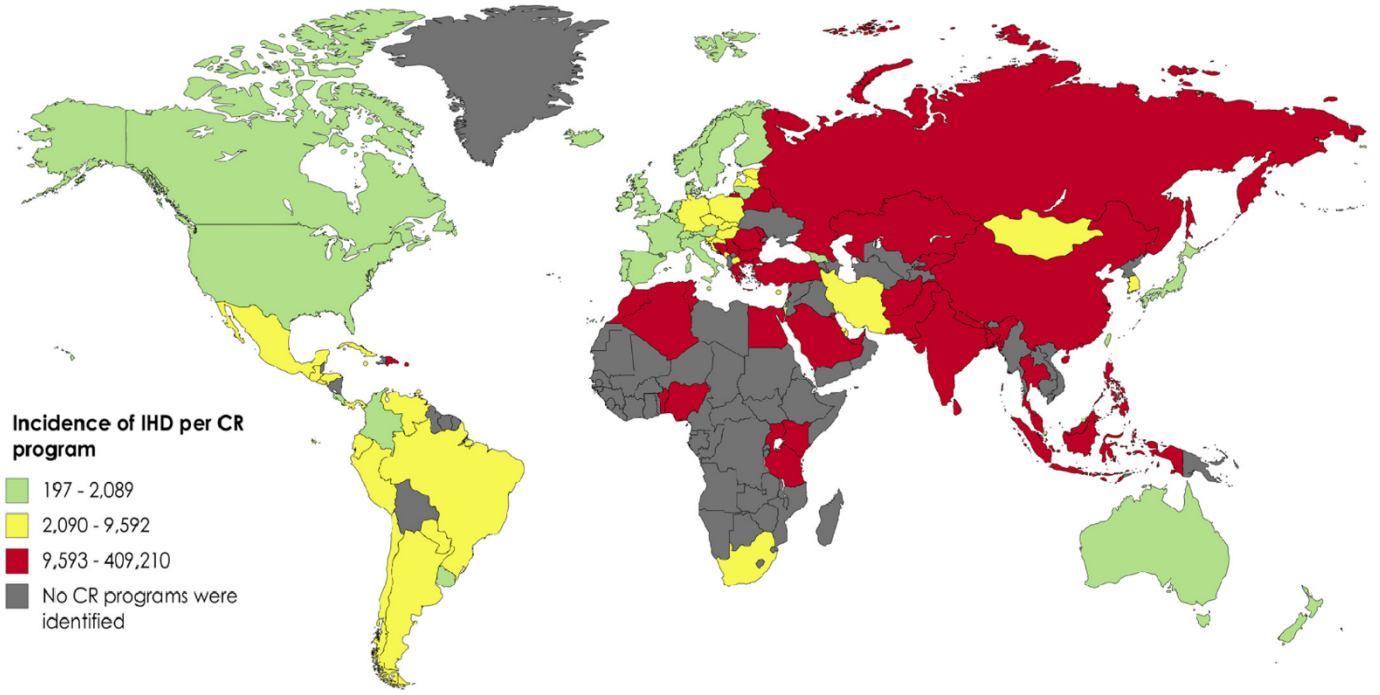

Fig. 3. Ischemic heart disease incidence by number of cardiac rehabilitation programs in a country. IHD, ischemic heart disease; CR, cardiac rehabilitation.

the data herein, a median of 180 patients were served per program) [12], and was surprisingly low. Programs were not quite running at full capacity, but this is likely explained by insufficient referral. Some potentially-modifiable factors associated with greater program volumes were offering alternative models (e.g., home-based CR) and having a mix of private and public program funding sources. We must advocate for governments to invest in CR and enact policies promoting insurance company reimbursement, and we must support CR programs to deliver services outside major clinical centers so we can reach the vast number of patients in need. Some guidance on CR delivery in alternative settings in low-resource countries is available [26,27]. Indeed in the Americas and Europe where availability and capacity are greatest, there was more often hybrid funding and more programs offered alternative models (data not shown).

The fact that programs served more patients where there were other programs in close proximity, when they were situated in an institution offering advanced cardiac procedures and with systematic inpatient referral, with a cardiologist on staff and where they served more patients per session and per staff member likely reflects the fact that programs at major academic centers are generally in urban centers and larger, and hence have higher volumes. The fact that residential programs, those serving high-risk primary prevention patients, and those where patients received an individual consult with a physician again is somewhat expected, but it is not recommended that programs pursue these avenues to increase reach, as they may be cost-prohibitive. It was disconcerting to find that programs offering more core components served fewer patients, as we do want to ensure reach to all patients in need, while maintaining quality and minimum standards (although higher-volume programs were more often providing smoking cessation services which is encouraging). Research is needed to understand how countries with the greatest capacity have achieved their heights, including the role of session volume, i.e., number of patients per session; while maintaining safety, so that it can be replicated elsewhere.

4.1. Policy Implications

There is grossly insufficient CR availability and capacity to meet global service needs. This problem must be addressed through initiation of new CR programs and increasing capacity of existing programs (this is a key finding of this work as program volumes were surprisingly low in most instances). This requires financial resources, which was the most commonly-reported barrier to broader provision of CR in this

Notes to Table 3:
*Private sources included healthcare insurance or patients; public included government; or a hybrid source. There was no statistically significant difference between privately and publicly funded program in the volume of patients served, but there was between hybrid and private with more patients for hybrid.
†i.e. cardiologist, physiatrist, sports medicine physician, nurse/practitioner, physiotherapist, exercise specialist/kinesiologist, psychiatrist/psychologist/social worker, dietitian, pharmacist, community health worker, administrative assistant/secretary, other; part-time staff were counted as 0.5.
‡Sessions/week × # weeks in program × # minutes per session.
§Of ten; i.e., initial assessment, risk stratification, supervised exercise, patient education, risk factor management, nutrition counseling, stress management, smoking cessation, prescription of medication, and communication with a primary healthcare provider.
||e.g., treadmills, cycle ergometers, supplies for cardiovascular risk assessment.
–Not applicable.
°Note that odds ratios can be misleading, and therefore the practical importance of the value should not be over-interpreted.
Acronyms: CR, cardiac rehabilitation; SD, standard deviation; GLMM, generalized linear mixed model; OR, odds ratio; CI, confidence interval; VAD, ventricular assist device; USD, United States dollar; PPP, purchase power parity.
Abbreviations: km, kilometers; Ref, reference.
Note: Due to missing data, percentages are computed where the denominator is the number of valid responses from responding programs.

Table 4
Barriers to Broader Cardiac Rehabilitation Delivery, by Country with Cardiac Rehabilitation & WHO Regions [32], N = 111.

Mean ± standard deviation*	number of CR programs	Lack of patient referral	Lack of equipment	Lack of space	Lack of human resources	Lack of financial resources
Africa						
Algeria	1	–	–	–	–	–
Kenya	3	5.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	4.0 ± 0.0	2.0 ± 0.0
Mauritius	1	5.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0
Nigeria	1	5.0 ± 0.00	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
South Africa	23	4.4 ± 1.0	1.8 ± 0.9	1.8 ± 1.1	2.0 ± 1.3	3.5 ± 1.7
Regional Mean	*5.8*	*4.5 ± 0.9*	*2.1 ± 1.3*	*2.2 ± 1.5*	*2.4 ± 1.5*	*3.5 ± 1.6*
Americas						
Argentina	23	5.0 ± 0.0	3.0 ± 1.7	1.7 ± 1.2	3.3 ± 1.2	3.7 ± 0.6
Barbados	1	5.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	5.0 ± 0.0	4.0 ± 0.0
Bermuda	1	2.0 ± 0.00	2.0 ± 0.0	3.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
Brazil	75	4.2 ± 1.2	2.4 ± 1.5	2.5 ± 1.6	2.9 ± 1.7	3.4 ± 1.5
Canada	170	2.5 ± 1.5	2.7 ± 1.3	3.2 ± 1.4	3.8 ± 1.4	4.3 ± 1.2
Chile	10	5.0 ± 0.0	4.0 ± 0.0	3.0 ± 0.0	3.0 ± 0.0	3.0 ± 0.0
Colombia	50	3.9 ± 1.5	2.1 ± 1.3	2.4 ± 1.3	2.3 ± 1.4	2.9 ± 1.4
Costa Rica	6	3.5 ± 1.6	2.3 ± 2.1	2.5 ± 2.0	3.0 ± 1.7	3.0 ± 1.7
Cuba	8	2.0 ± 1.3	3.4 ± 1.5	3.5 ± 1.9	2.3 ± 1.5	2.4 ± 1.5
Curacao	2	4.0 ± 0.0	2.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0
Dominican Republic	2	5.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	4.0 ± 0.0	2.0 ± 0.0
Ecuador	5	5.0 ± 0.0	1.5 ± 0.7	1.0 ± 0.0	1.5 ± 0.7	1.5 ± 0.7
Guatemala	2	5.0 ± 0.0	3.0 ± 1.4	3.0 ± 1.4	3.5 ± 2.1	2.5 ± 0.7
Honduras	2	3.0 ± 0.0	2.0 ± 0.0	3.0 ± 0.0	3.0 ± 0.0	5.0 ± 0.0
Jamaica	3	5.0 ± 0.0	2.0 ± 0.0	1.0 ± 0.0	2.0 ± 0.0	1.0 ± 0.0
Mexico	24	4.9 ± 0.3	1.9 ± 1.5	3.1 ± 1.5	3.1 ± 1.5	3.9 ± 1.4
Panama	1	5.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0
Paraguay	3	5.0 ± 0.0	2.0 ± 0.0	3.3 ± 1.2	4.0 ± 0.0	3.7 ± 1.5
Peru	10	3.4 ± 1.5	3.7 ± 1.5	3.3 ± 1.8	4.0 ± 1.5	4.1 ± 1.2
United States of America	2632	3.5 ± 1.4	2.6 ± 1.4	3.0 ± 1.4	2.9 ± 1.2	3.2 ± 1.5
Uruguay	12	4.3 ± 1.5	1.5 ± 0.6	1.6 ± 0.9	1.3 ± 0.5	4.5 ± 0.6
Venezuela	9	3.8 ± 1.8	3.6 ± 1.8	1.9 ± 1.5	3.1 ± 1.5	4.4 ± 1.1
Regional Mean	*138.7*	*3.5 ± 1.5*	*2.5 ± 1.5*	*2.8 ± 1.5*	*3.1 ± 1.5*	*3.5 ± 1.5*
Eastern Mediterranean						
Afghanistan	1	4.0 ± 0.0	5.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
Bahrain	1	5.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	5.0 ± 0.0	3.0 ± 0.0
Egypt	2	5.0 ± 0.0	4.0 ± 0.0	3.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0
Iran	34	4.8 ± 0.5	2.3 ± 1.3	2.5 ± 1.4	2.8 ± 1.5	4.0 ± 1.2
Lebanon	1	4.0 ± 0.0	1.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	5.0 ± 0.0
Morocco	1	–	–	–	–	–
Pakistan	4	5.0 ± 0.0	2.5 ± 2.1	3.0 ± 1.4	3.5 ± 0.7	4.5 ± 0.7
Qatar	1	1.0 ± 0.0	3.0 ± 0.0	5.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0
Tunisia	1	5.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	2.0 ± 0.0
Regional Mean	*5.1*	*4.6 ± 0.9*	*2.4 ± 1.4*	*2.6 ± 1.4*	*3.1 ± 1.4*	*4.1 ± 1.1*
Europe						
Austria	26	2.4 ± 1.9	1.3 ± 0.5	1.3 ± 0.5	2.0 ± 1.4	1.8 ± 1.5
Belarus	5	3.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0
Belgium	48	4.0 ± 1.1	2.1 ± 1.4	2.1 ± 1.1	2.4 ± 1.4	2.9 ± 1.5
Bosnia and Herzegovina	1	1.0 ± 0.0	4.0 ± 0.0	1.0 ± 0.0	4.0 ± 0.0	1.0 ± 0.0
Bulgaria	1	2.0 ± 0.0	2.0 ± 0.0	1.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0
Croatia	3	3.7 ± 0.6	2.7 ± 1.5	2.7 ± 1.5	3.0 ± 1.0	3.7 ± 1.5
Czech Republic	15	3.8 ± 1.3	2.4 ± 1.5	3.0 ± 1.9	3.4 ± 1.3	2.6 ± 1.3
Denmark	35	3.6 ± 0.5	2.2 ± 1.2	2.7 ± 1.1	3.4 ± 1.5	3.4 ± 1.8
England	266	2.0 ± 1.3	2.1 ± 1.1	2.9 ± 1.4	3.3 ± 1.3	3.3 ± 1.3
Estonia	2	2.0 ± 1.4	4.0 ± 1.4	5.0 ± 0.0	5.0 ± 0.0	3.0 ± 0.0
Finland	25	3.8 ± 1.2	1.4 ± 0.7	2.2 ± 1.5	2.8 ± 1.3	2.9 ± 1.3
France	130	3.6 ± 1.6	2.4 ± 1.5	3.3 ± 1.6	3.5 ± 1.5	2.8 ± 1.1
Georgia	17	2.9 ± 1.3	1.1 ± 0.4	2.1 ± 1.6	2.1 ± 1.0	4.0 ± 1.4
Germany	120	4.0 ± 1.3	1.6 ± 0.9	2.2 ± 1.4	2.4 ± 1.3	2.9 ± 1.6
Greece	4	4.3 ± 1.5	1.0 ± 0.0	1.3 ± 0.5	1.8 ± 1.5	4.8 ± 0.5
Hungary	33	4.2 ± 1.3	2.8 ± 1.3	2.6 ± 1.2	3.1 ± 1.4	3.3 ± 1.4
Iceland	4	1.5 ± 0.6	2.0 ± 1.4	1.3 ± 0.5	1.8 ± 1.0	4.5 ± 0.6
Ireland	37	2.6 ± 1.1	1.8 ± 0.8	3.4 ± 1.8	3.8 ± 0.8	3.0 ± 0.7
Israel	22	2.8 ± 1.8	1.4 ± 0.6	2.4 ± 1.7	3.0 ± 1.9	2.8 ± 1.6
Italy	221	3.5 ± 1.5	2.6 ± 1.4	2.7 ± 1.4	3.3 ± 1.5	3.6 ± 1.3
Kazakhstan	1	0	3.0 ± 0.0	2.0 ± 0.0	3.0 ± 0.0	4.0 ± 0.0
Latvia	2	5.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	3.0 ± 0.0	5.0 ± 0.0
Lithuania	25	2.6 ± 1.0	2.4 ± 1.1	2.3 ± 1.1	2.9 ± 1.2	4.6 ± 0.7
Republic of Northern Macedonia	1	4.0 ± 0.0	3.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	5.0 ± 0.0
Malta	1	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.00	5.0 ± 0.00	5.0 ± 0.0
Moldova	1	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0
Netherlands	90	2.1 ± 1.4	1.6 ± 1.2	2.1 ± 1.5	2.4 ± 1.3	2.7 ± 1.6
Northern Ireland	13	2.1 ± 1.5	2.3 ± 1.5	3.2 ± 1.6	4.6 ± 1.0	4.7 ± 0.9
Poland	56	3.0 ± 1.4	2.0 ± 1.3	2.9 ± 1.4	2.7 ± 1.3	3.6 ± 1.4
Portugal	23	4.2 ± 1.3	3.1 ± 1.4	3.5 ± 1.4	3.6 ± 1.5	4.6 ± 0.9

Table 4 (*continued*)

Mean ± standard deviation*	number of CR programs	Lack of patient referral	Lack of equipment	Lack of space	Lack of human resources	Lack of financial resources
Romania	3	4.5 ± 0.7	1.5 ± 0.7	1.5 ± 0.7	2.5 ± 2.1	3.0 ± 2.8
Russia	3	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0
Scotland	69	1.9 ± 1.4	1.6 ± 0.8	2.1 ± 1.1	2.8 ± 1.3	2.6 ± 1.3
Serbia	2	3.0 ± 0.0	2.0 ± 1.4	2.5 ± 0.7	2.5 ± 0.7	3.5 ± 2.1
Slovak Republic	7	3.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	5.0 ± 0.0
Slovenia	2	4.5 ± 0.7	2.0 ± 1.4	2.5 ± 2.1	3.0 ± 1.4	3.5 ± 0.7
Spain	87	3.2 ± 1.4	3.1 ± 1.4	3.2 ± 1.4	3.7 ± 1.4	3.7 ± 1.4
Sweden	69	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	3.0 ± 0.0	3.0 ± 0.0
Switzerland	51	2.8 ± 1.5	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	1.3 ± 0.5
Turkey	10	4.5 ± 1.4	2.4 ± 1.5	2.4 ± 1.1	3.5 ± 1.2	2.4 ± 1.3
Wales	17	2.2 ± 1.4	2.3 ± 1.2	3.6 ± 1.6	4.7 ± 0.6	4.6 ± 0.6
Regional Mean	*37.8*	*3.1 ± 1.5*	*2.3 ± 1.3*	*2.7 ± 1.4*	*3.2 ± 1.4*	*3.4 ± 1.4*
South-East Asia						
Bangladesh	1	5.0 ± 0.0	2.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
India	23	3.9 ± 1.4	2.3 ± 1.4	2.3 ± 1.4	2.4 ± 1.6	3.2 ± 1.8
Indonesia	13	3.5 ± 1.7	2.9 ± 1.5	2.9 ± 1.7	2.8 ± 1.6	3.0 ± 1.4
Nepal	1	4.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0
Sri Lanka	4	1.5 ± 0.7	3.5 ± 2.1	3.0 ± 1.4	3.5 ± 2.1	1.5 ± 0.7
Regional Mean	*8.4*	*3.7 ± 1.5*	*2.6 ± 1.4*	*2.7 ± 1.4*	*2.7 ± 1.6*	*3.1 ± 1.6*
Western Pacific						
Australia	314	3.4 ± 1.4	2.5 ± 1.3	3.1 ± 1.4	3.5 ± 1.5	3.5 ± 1.4
Brunei	2	4.5 ± 0.7	2.5 ± 2.1	3.0 ± 2.8	3.0 ± 2.8	2.0 ± 1.4
China	216	3.1 ± 1.4	2.7 ± 1.4	3.1 ± 1.5	3.3 ± 1.3	3.9 ± 1.4
Japan	325	3.0 ± 1.3	2.7 ± 1.6	3.4 ± 1.4	4.3 ± 0.9	3.1 ± 1.1
Malaysia	6	3.7 ± 1.5	2.7 ± 2.1	3.0 ± 1.7	3.0 ± 1.7	3.3 ± 1.5
Mongolia	1	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
New Zealand	43	2.9 ± 1.4	2.9 ± 1.4	3.0 ± 1.6	3.4 ± 1.2	3.8 ± 1.3
Philippines	10	4.3 ± 0.5	3.0 ± 1.2	3.6 ± 1.7	3.2 ± 1.1	3.8 ± 1.3
Singapore	7	4.4 ± 0.5	2.0 ± 1.4	2.6 ± 1.7	4.1 ± 1.1	3.4 ± 1.1
South Korea	17	3.1 ± 1.3	1.4 ± 0.5	1.8 ± 1.1	2.1 ± 0.9	3.8 ± 1.3
Taiwan	35	3.1 ± 1.4	2.6 ± 1.5	2.9 ± 1.3	3.2 ± 1.4	2.4 ± 1.3
Regional Mean	*88.7*	*3.3 ± 1.4*	*2.6 ± 1.4*	*3.0 ± 1.5*	*3.4 ± 1.4*	*3.6 ± 1.4*
Global Mean	*61.2*	*3.3 ± 1.5*	*2.4 ± 1.4*	*2.8 ± 1.5*	*3.2 ± 1.4*	*3.5 ± 1.4*

*Scores range from 1 (this is definitely not an issue) to 5 (this is a major issue).
Acronyms: WHO, World Health Organization; FYR, Former Yugoslav Republic.

study, as well as others [9,28]. Affordable models of CR delivery should be implemented given the need in low and middle-income countries [27,29]. Offering alternative models such as home-based and community-based programs could increase capacity of existing CR programs. Information and communications technology should be exploited to increase the number of patients each program can treat, while maintaining program quality and safety [30]. It is essential for CR associations and other international societies to advocate for CR implementation and reimbursement; advocacy tools are available from the ICCPR [28]. This association also offers a certification program for healthcare professionals, which could address the reported barrier of lack of human resources to deliver CR [31].

4.2. Limitations

There are some weaknesses of study methodology, primarily related to generalizability and measurement. First, some programs may not have been identified, especially in countries where no society or champion was identified. Therefore, availability, capacity and density could be under-estimated. Second, though a high response rate at the country-level of 85% was achieved, response rates among programs within countries were only 1/3, and hence there may be bias (i.e., ascertainment bias). In particular, high-resourced programs, which serve a larger number of patients, may have been more likely to be represented in the sample; this could result in over-estimates on capacity indicators.

The other main limitation relates to measurement. First, IHD incidence is estimated by GBD in many countries, and thus measurement error is expected. Second, volume drivers were chosen based on investigator opinion from the variables available in the survey; the survey was developed to assess the nature of programs, not drivers of volume. There are likely unmeasured factors at play. For this reason, readers should use caution when interpreting the results from the test of drivers. These should be considered exploratory at this stage, with future research needed to further investigate. Third, national capacity was computed by multiplying the median capacity in responding programs by the total number of programs; given not all programs responded to the survey where capacity was reported, and that program-reported capacity values were not validated in a random subsample of programs (nor were volumes or drivers of volume assessed); this would also introduce some error. These values were used to compute density estimates, which therefore should also be interpreted with some caution.

On a related note, there are some measurement issues related to CR density specifically. It has been estimated based on IHD incidence only for reasons outlined above, and therefore without considering heart failure, density is surely over-estimated. Additionally, the term CR density has been variably operationalized in the literature (e.g., ratio of population to number of programs), and hence comparisons to values reported in other studies should not be undertaken. This is the first study to have been able to characterize CR density as spots per indicated patient specifically, and it is hoped that in future studies this more accurate approach will be applied. Understanding the incidence of CR-indicated conditions (i.e., IHD and heart failure) on a national basis globally is another important area for further work (crudely, the annual incidence of CVD globally is 422.7 million cases [2]; given the number of CR spots globally, this suggests a density of 1 spot per 255 CVD patients), as is identifying drivers of density.

There also some broader limitations that should be considered. The first concerns practical importance of the findings. The significance of the inferential tests reported herein should not be interpreted to suggest significance from a health system, practice or clinical perspective. Second, due to the nature of the design, causal conclusions should not be drawn. Finally, due to multiple tests, there could be inflated error.

In conclusion, despite guideline recommendations that CVD patients should access CR, it is only available in half of countries around the world, and where available, density was grossly insufficient to serve all patients in need. Programs offering alternative models and that are funded by multiple sources treated more patients than those that are not. Advocacy for more programs that each serve the maximal number of patients safely is needed to ensure all guideline-indicated patients achieve the reductions in cardiovascular mortality and morbidity associated with CR participation.

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Authors' Contributions

KTA contributed to study design, data acquisition (i.e., identifying countries with cardiac rehabilitation and contacting champions to collect data from programs), data analysis and co-drafted the manuscript; MS conducted data collection; FLJ had substantial contributions to conception and design of work; facilitation of data collection in South America; EP assisted in data cleaning and drafting display items; RD, RB, BBW, WD, AA, ASB, CAS, SKJ, LC, TJY, DS, KA, GG, VG, DV, EV, JC, EK, IY, CK, BB, ERE, RF, BR, DG, AS, SYC, BR, JCM, LM, GB, RS, HL, MS, ES, AH, ETP, MA, LN, EA, HK, ZE, SF, JH, EP, SD, CS, CZ, BP, AK, NS, CB, RT, and DH arranged data collection from the cardiac rehabilitation programs in their country (sampling) and revised the manuscript critically for important intellectual content. S.L.G. was responsible for the conception and design of the work, interpretation of the data, and drafting the manuscript. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors interpreted data and critically revised and approved the final manuscript. KTA is the guarantor. The corresponding author attests that all listed authors meet authorship criteria.

Declaration of Competing Interest

Dr. Derman reports some financial activities that were outside the submitted work (i.e., grants from International Olympic and Paralympic Committees, as well as personal fees from 2 advisory boards). All other authors declare no financial or personal interests.

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