Research Square

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Clinic vs Screen: Comparing Fully In-Person to Virtual-Plus–In-Person Cardiac Fitness and Rehabilitation Programs for Congenital Heart Disease

Tracy Curran
tracy.curran@cardio.chboston.org
Boston Children's Hospital
Jennifer Pymm
Boston Children's Hospital
Joanne Gabriel
Boston Children's Hospital
Allison Flanagan
Boston Children's Hospital
Kimberlee Gauvreau
Boston Children's Hospital
Naomi Gauthier
Boston Children's Hospital

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Abstract

Cardiac fitness and rehabilitation programs offer meaningful benefits for individuals with congenital heart disease (CHD), and newer delivery models include hybrid formats combining virtual and in-person training. We hypothesized that the convenience of hybrid delivery would improve program adherence and patient satisfaction while remaining safe and effective compared with in-person training alone. In this retrospective cohort study of 158 participants with CHD (68 in-person, 90 hybrid), groups were similar at baseline, including distance traveled, except for sex ($p = 0.035$) and hemodynamic level ($p = 0.002$). Both groups demonstrated significant pre- to post-program improvements in aerobic capacity, strength, and flexibility, with few between-group differences and no adverse events. Psychologic outcomes favored the hybrid group, with greater gains in self-efficacy ($p = 0.017$) and larger reductions in parent-reported patient anxiety ($p = 0.02$). A trend toward greater fitness progression from entry to advanced level was seen in the hybrid group (32% vs. 21%), though not reaching statistical significance. Contrary to our hypothesis, adherence was comparable between groups (median 19 vs. 16 sessions, $p = 0.15$). Satisfaction was high for both (93% vs. 97%, $p = 0.74$), though notably, among hybrid participants completing both session types, in-person was preferred ($p < 0.001$). Thus, each delivery model produced meaningful, safe fitness improvements in patients with CHD. Hybrid delivery achieved benefits comparable to, or exceeding, fully in-person programming, yet in-person sessions were preferred and did not sacrifice adherence, suggesting direct social connection is valued. As the field moves toward technology-enabled delivery, these findings support flexible models integrating virtual training while preserving social connection.

Introduction

Children with congenital heart disease (CHD) often have lower cardiorespiratory fitness when compared to their peers without disease [1, 2], with faster declines in fitness and impaired health-related quality of life (HRQoL) [3, 4, 5]. The global COVID-19 pandemic furthered that divide [6, 7] but also ushered in a new era of utilizing a virtual environment for healthcare, including virtual telehealth exercise programs [3, 8, 9, 10, 11]. In-person cardiac fitness and rehabilitation (CFR) programs have demonstrated benefits for patients with CHD, including sustained improvements in exercise function, self-esteem, behavior, and emotional state [12, 13] and have also been shown to be safe with no major adverse events [8, 12, 14, 15, 16, 17]. However, traditional in-person CFR faces barriers such as accessibility, social circumstances, and cost, limiting adherence, particularly in CHD populations with varying disease complexity [17].

Adult cardiac rehabilitation programs have addressed these barriers by offering hybrid delivery models consisting of a mix of in-person and supervised virtual sessions, improving accessibility and adherence [18, 19]. Telehealth-based adult cardiac rehabilitation enhances physical activity levels, exercise capacity, and modifiable risk factors without increasing mortality or adverse events [20, 21]. For adult populations, hybrid and virtual cardiac rehabilitation yield improvements in functional capacity, blood pressure control, and anxiety equivalent to in-person delivery, with both formats well received by patients and providers. For youth with CHD, hybrid CFR has shown measurable improvements with good acceptability and safety [3, 8, 22, 23], but gaps persist in understanding outcomes of hybrid versus in-person CFR in this population.

This retrospective cohort study evaluated outcomes from in-person only delivery vs. hybrid delivery for patients with CHD. We hypothesized that hybrid programs would demonstrate comparable improvements in physiologic metrics, psychologic well-being, and safety relative to in-person only programs, but that adherence and satisfaction would be greater among hybrid participants.

Methods

Patients enrolled in a CFR program between January 2017 through March 2025 were consented and their data were entered in a prospective REDCap registry [24, 25]. This retrospective study used data from the IRB-approved Cardiac Fitness Program Registry (Protocol IRB-P00030570). All participants or their legally authorized guardian provided

informed consent for inclusion in the registry. The current retrospective analysis was conducted under the existing registry approval, with no separate IRB approval or HIPAA authorization/waiver required. Data included geographic distance from the center, age, sex, height, weight, and body mass index. The participant's congenital or acquired heart conditions was classified as simple or complex congenital heart disease, single ventricle physiology, primary pulmonary hypertension (PHTN), inherited arrhythmias, cardiomyopathy, or post- heart transplant status as previously described (8). Each participant was evaluated and risk stratified into a FORCE category for intensity training based on hemodynamic level (FORCE 1 has the lowest hemodynamic burden, FORCE 2 moderate burden, and FORCE 3 greatest hemodynamic burden) [26]. Delivery mode (in person vs hybrid), session numbers, and training progression were collected and recorded.

Effectiveness was assessed by physiologic metrics. Aerobic capacity was determined via a cardiopulmonary exercise test (CPET) at baseline and at 6 months. CPETs used cycle ergometer (ramp protocol) or treadmill (step or ramping Bruce protocol) with expired gases analyzed using the Ultima CPX™ system. Peak oxygen consumption (VO_2) was determined at the highest reliable exercise value, and percent predicted peak VO_2 ($pppVO_2$) was calculated with standard clinical prediction equations, best fit for age, height, and weight. METs were assessed using exercise duration on both modalities. Ventilatory anaerobic threshold (VAT) followed standard determination methods. Exercise test data were excluded if submaximal (respiratory exchange ratio < 1.09). Strength was assessed in upper (number of modified or standard push-ups), core (plank hold in seconds), and lower body (number of squats) categories. Flexibility was evaluated using a sit-and-reach test. For pediatric patients, mindset was measured using patient and parent Patient-Reported Outcomes Measurement Information System (PROMIS) Meaning and Purpose scales to both patients and parents. Scores around 50 represent the average US child, with lower indicating less of the measured trait and higher indicating more of the measured trait [27, 28]. In addition, General Self-Efficacy Scale and Growth Mindset surveys were completed by participant [29, 30, 31, 32]. Strength, flexibility and mindset metrics were assessed at baseline and every 30 days until program completion.

An individualized exercise prescription was developed based on FORCE category and CPET findings. Based on timing (virtual training was not offered before 2021), patient/family preference, or clinician determination of safety or behavioral ability to participate in remote training, patients either participated in all in-person or hybrid (blend of in person and virtual) training. Hybrid participants had to complete at least 3 in-person sessions with telemetry prior to attending virtual sessions. All in person sessions lasted up to 60 minutes with one-to-one training conducted by an exercise physiologist and included both exercise training and education for physical and mental fitness. Virtual fitness sessions were conducted with one-to-one interaction between the participant and an exercise physiologist via synchronous video on the hospital's telehealth platform. Each virtual visit lasted between 31–60 minutes, with exercise and education being delivered simultaneously. During both virtual and in-person training, heart rate and/or rate of perceived exertion (RPE) was reported to monitor exercise intensity. Every 30 days benchmarking for exercise progression was performed for both groups. Patients progressed from entry to intermediate or advanced levels after reaching predetermined exercise volume targets based on frequency, intensity, and duration. The program length lasted up to 3 months.

Safety was assessed through monitoring of adverse events. Participant satisfaction was evaluated using post-program surveys with Likert scale classifications, covering overall program content, facilities, and both in-person and virtual fitness session quality. Adherence was defined based on the number of sessions attended. Progression was assessed by movement between entry, intermediate, and advanced levels of training. Geographic distance was calculated as the number of miles from participants' home addresses to their chosen fitness location.

Categorical variables were summarized using frequencies and percentages, and continuous variables using either medians and ranges or means with standard deviations. Characteristics of patients with in-person only visits versus a hybrid strategy were compared using Fisher's exact test for categorical variables and Wilcoxon rank sum tests for

continuous measurements. Changes in physiological and mindset variables pre- to post-program were evaluated using paired t tests for mean changes and Wilcoxon signed-rank tests for median changes. Analyses were performed in Stata version 18.

Results

Baseline Characteristics

A total of 158 participants met eligibility criteria, with 68 in the in-person group and 90 in the hybrid group. Baseline demographics for the total cohort, in-person only, and hybrid group are summarized in Table 1. Median age for the cohort was 17.9 years. The most common disease classification was complex CHD (44%). Hybrid participants were more likely female (62% vs. 46%, $p = 0.035$) and FORCE 1 level (69% vs. 46% $p = 0.002$) than in-person only participants, with no significant differences in age, BMI, height, or weight. Although disease classification between groups may have borderline differences ($p = 0.051$), both groups included a full mix of disease types (Fig. 1).

Table 1
Baseline characteristics

Age at entry, years	**Total cohort (n = 158)**	**In-person only (n = 68)**	**Hybrid (n = 90)**	***p* value**
	17.9 (8.7, 57.3)	**17.8 (8.7, 52.4)**	**18.2 (9.2, 57.3)**	**0.31**
Age at entry ≥ 21 years	54 (34%)	19 (28%)	35 (39%)	0.18
Sex	70 (44%)	37 (54%)	34 (37%)	0.035
Male	87 (55%)	31 (46%)	56 (62%)	
Female	1 (1%)	0 (0%)	1 (1%)	
Other				
Height, cm (n = 157, 67, 90)	162 (124, 197)	163 (124, 190)	162 (129, 197)	0.64
Weight, kg (n = 157, 67, 90)	64 (22, 146)	64 (22, 146)	64 (32, 127)	0.80
Body mass index, kg/m^2 (n = 157, 67, 90)	24.5 (14.0, 49.2)	24.1 (14.0, 46.4)	25.1 (14.9, 49.2)	0.63
Disease classification				0.051
Simple CHD	23 (15%)	6 (9%)	17 (19%)	
Complex CHD	69 (44%)	26 (38%)	43 (48%)	
Single ventricle	26 (16%)	14 (21%)	12 (13%)	
Primary PHTN	4 (3%)	2 (3%)	2 (2%)	
Arrhythmia	8 (5%)	7 (10%)	1 (1%)	
Cardiomyopathy	11 (7%)	4 (6%)	7 (8%)	
Transplant	17 (11%)	9 (13%)	8 (9%)	
FORCE intensity level at program entry				0.002
FORCE 1	93 (59%)	31 (46%)	62 (69%)	
FORCE 2	46 (29%)	22 (32%)	24 (27%)	
FORCE 3	16 (10%)	12 (18%)	4 (4%)	
Undetermined	3 (2%)	3 (4%)	0 (0%)	

Categorical variables are summarized as numbers and percentages, and continuous variables as medians and ranges

Physical Fitness Changes

Pre-post physiologic changes for the in-person only and hybrid groups are shown in Table 2. Among those with paired CPET at both time points (n = 97), percent predicted peak VO_2 increased in both groups (in-person: 5.1 ± 9.5%, $p = 0.002$; hybrid: 3.0 ± 8.9%, $p = 0.014$), but METs increased significantly only in-person (0.6 ± 1.2, $p = 0.002$); the change was greater in-person when compared between groups ($p = 0.010$). VAT at VO_2 increase in both groups, but only the hybrid

group was statistically significant ($p = 0.041$). All strength and flexibility measures increased in both groups, with greater plank time gains in the hybrid group when comparing to in-person ($p = 0.034$).

Table 2
Physiological comparison within and between each group for absolute change pre- to post-program

		In-person only		Hybrid		In-person only vs hybrid
	n	Absolute change	*p* value pre to post	Absolute change	*p* value pre to post	*p* value for group differences
Aerobic*						
METS (peak)	40, 57	0.6 ± 1.2	0.002	-0.1 ± 1.4	0.63	0.010
RER (peak)	40, 57	0.03 ± 0.09	0.057	0.01 ± 0.09	0.41	0.32
Percent predicted peak VO_2	40, 57	5.1 ± 9.5	0.002	3.0 ± 8.9	0.014	0.28
Percent predicted VAT at VO_2	40, 51	1.6 ± 6.1	0.11	2.5 ± 8.7	0.041	0.52
Strength						
Push-ups	53, 88	6 [1, 10]	< 0.001	6 [2, 11]	< 0.001	0.49
Squats	9, 35	12 [6, 20]	0.016	16 [10, 30]	< 0.001	0.36
Planks (sec)	58, 88	16 [5, 27]	< 0.001	26 [9, 41]	< 0.001	0.034
Flexibility						
Sit and reach (cm)	61, 82	3.2 ± 5.1	< 0.001	3.6 ± 4.0	< 0.001	0.59
*Aerobic variables summarized only if RER ≥ 1.09						

Mean ± standard deviation or median [25th, 75th percentiles]

Progression to advanced level of the fitness prescription occurred in 31% of the cohort (39% in the hybrid vs. 21% of the in-person groups); 86% of the cohort advanced by at least one level. A greater proportion of patients in the hybrid group increased from entry to advanced level during the program (32% vs 21%), and fewer did not advance at all (11% versus 19%), but this difference between groups does not achieve statistical significance ($p = 0.15$), see Fig. 2.

Mindset Changes

Mindset changes are shown in Table 3. Meaning and Purpose improved for both the participant self-report (3 ± 6, $p = 0.002$) and parent-report of their child (6 ± 9, $p = 0.003$) in the hybrid group. While the Meaning and Purpose scores increased in the in-person group, they did not reach statistical significance, and there was no statistical significance between groups. For Anxiety, improvement was seen for parent-report of their child in the hybrid group (-7 ± 8, $p = 0.006$), and this advantage of the hybrid format persisted when comparing between groups ($p = 0.020$). Self-efficacy increased

more in hybrid group compared to in-person only (0.3 ± 0.4 vs. 0.0 ± 0.33, $p = 0.017$). No significant change in Growth Mindset was found between groups.

Table 3
Mindset comparison of In-person versus Hybrid, changes within and between pre- to post-program

	n	In-person Only		Hybrid		In-person only vs hybrid
		Absolute change	***p* value pre to post**	**Absolute change**	***p* value pre to post**	***p* value for group differences**
Meaning and Purpose						
Participant	24, 35	2 ± 6	0.075	3 ± 6	0.002	0.42
Parent	21, 24	1 ± 8	0.47	6 ± 9	0.003	0.074
Anxiety						
Participant	15, 16	-4 ± 9	0.11	-2 ± 8	0.41	0.48
Parent	13, 13	0 ± 8	0.86	-7 ± 8	0.006	0.020
Self-Efficacy	18, 31	0.00 ± 0.3	0.71	0.3 ± 0.4	< 0.001	0.017
Growth Mindset	18, 31	0.2 ± 1.0	0.34	0.4 ± 1.7	0.20	0.71

Program Outcomes

Program data is represented in Table 4. Adherence was similar in both groups with a median of 18 total sessions (in-person: 16 in-person; hybrid: 9 in-person + 9 virtual). There was also no significant difference in driving distance between the two groups ($p = 0.72$). Program satisfaction (n = 106 responders) overall was high (82% very satisfied with program), among those who responded, there were no significant difference in satisfaction with the program, facilities, or in-person session. However, for the 65 hybrid subjects who answered both questions about in-person vs. virtual training, in-person sessions rated higher than virtual (83% very satisfied with in-person sessions vs 57% with virtual sessions, ($p < 0.001$). No major adverse events were noted for either group.

Table 4
Program data comparison of In-person versus Hybrid

Total number of sessions	**Total Cohort (n = 158)**	**In-person Only (n = 68)**	**Hybrid (n = 90)**	***p* Value**
	18 (3, 40)	**16 (3, 40)**	**19 (3, 25)**	**0.15**
In-person sessions	11 (3, 40)	16 (3, 40)	9 (3, 22)	--
Virtual sessions (n = 90)	--	--	9 (0, 16)	--
Driving distance	22 (1, 244)	23 (1, 105)	20 (1, 244)	0.72
Program (n = 106)	87 (82%)	30 (88%)	57 (79%)	0.74
Very satisfied	13 (12%)	3 (9%)	10 (14%)	
Satisfied	3 (3%)	1 (3%)	2 (3%)	
Neutral	0 (0%)	0 (0%)	0 (0%)	
Unsatisfied	3 (3%)	0 (0%)	3 (4%)	
Very unsatisfied				
Facilities (n = 106)	74 (70%)	26 (76%)	48 (67%)	0.81
Very satisfied	22 (21%)	7 (21%)	15 (21%)	
Satisfied	5 (5%)	1 (3%)	4 (6%)	
Neutral	2 (2%)	0 (0%)	2 (3%)	
Unsatisfied	3 (3%)	0 (0%)	3 (4%)	
Very unsatisfied				
In-person sessions (n = 106)	91 (86%)	31 (91%)	60 (83%)	0.67
Very satisfied	10 (9%)	3 (9%)	7 (10%)	
Satisfied	2 (2%)	0 (0%)	2 (3%)	
Neutral	0 (0%)	0 (0%)	0 (0%)	
Unsatisfied	3 (3%)	0 (0%)	3 (4%)	
Very unsatisfied				
Virtual session (n = 65)	--	--	37 (57%)	--
Very satisfied			18 (28%)	
Satisfied			5 (8%)	
Neutral			2 (3%)	
Unsatisfied			3 (5%)	
Very unsatisfied				

Discussion

This study found that both hybrid and in-person cardiac fitness programs improved physiologic and mindset outcomes in patients with CHD. Importantly, both programs were safe across CHD severity levels, reinforcing existing evidence that structured exercise training carries acceptable risk and meaningful benefit regardless of delivery format [8, 14, 15].

Comparison of Physical Fitness and Mindset Outcomes

Both groups achieved improved physical and psychological metrics, with each delivery model demonstrating distinct advantages. The in-person participants achieved greater peak metabolic equivalents (METs), while hybrid participants demonstrated a greater strength metric (higher plank time), consistent with other studies showing hybrid and in-person formats both enhance muscular endurance and aerobic fitness capacity [3, 19, 22].

Across both groups, pre-to-post improvements in progression level (as measured by advancing through the entry, intermediate, and advanced levels of the exercise prescription scaled per patient) were achieved, likely reflecting the program's structured, progression-based design [33]. Degree of progression favored the hybrid group although this difference did not reach statistical significance and warrants cautious interpretation. The higher proportion of FORCE 1 participants, indicating less complex CHD in the hybrid group may account for this trend, as lower physiologic burden may allow faster progression through fitness levels.

Mindset outcomes were a notable strength of the hybrid model. Hybrid participants, by self-report and their parents' reports, demonstrated significant pre-to-post improvements in meaning and purpose (MaP), underscoring that cardiac fitness programming should target mindset training alongside physical performance, a principle supported by prior work linking positive mindset to higher VO_2 in CHD populations [3, 8, 32, 34]. Hybrid participants also reported greater self-efficacy post-program. This may reflect a confluence of factors: there were a higher proportion of participants with the highest exercise prescription due to least amount of hemodynamic considerations (FORCE 1) in the hybrid group and exposure to training conducted in the home environment, outside of the clinical setting, may have reinforced a sense of ownership and capability. Parents in the hybrid group similarly reported lower anxiety in their child, plausibly because observing their child exercise independently, without medical monitoring equipment present, reframed the activity as normalizing rather than medicalized. These findings extend the health-related quality of life benefits documented in other pediatric cardiac fitness programs [3] by quantifying psychological gains specific to hybrid delivery and align with evidence of equivalent functional outcomes across hybrid and in-person cardiac rehabilitation formats [18, 19, 22].

Comparison of Program Outcomes

Adherence was similar across both groups. Of note, our hybrid program did not start until 2021, so the adherence data for in-person sessions in the hybrid group were all from the post-pandemic era. Given the flexibility and ease that virtual sessions allow, the hypothesis was that hybrid participants would attend more sessions simply by virtue of convenience. However, both groups were essentially equivalent. This pattern, consistent with telehealth literature in both CHD and broader cardiac rehabilitation populations [3, 20, 35], may reflect something less logistical and more fundamentally human, that people are drawn to in-person social connection in ways that convenience alone does not override. Humans are social beings and the critical need for meaningful connection and risk for cardiovascular outcomes with loneliness has been described [36]. The inability to connect during the COVID-19 pandemic [36] may have amplified these needs leading to valuing the in-person sessions despite the inconvenience.

That interpretation is further supported by how participants felt about their experience. Satisfaction was high and comparable between groups overall, but within the hybrid group, participants rated in-person sessions significantly higher than virtual sessions. This points to an important aspect of program design: the assumption that virtual care will provide a welcome improvement may not always be accurate. Notably, geographic distance from the center did not

distinguish the groups, suggesting that proximity was not the primary driver of format preference. The data support what many clinicians observe in practice, that given the choice, many patients still want to come in. The physical presence of a provider, the shared space with the fitness team, and the immediacy of human connection may carry therapeutic weight that virtual delivery, for all its value, may not fully replicate [18].

Limitations

Several limitations should be considered. The retrospective design and absence of randomization introduce selection bias, particularly given baseline differences between groups, hybrid participants presented with higher baseline VO_2 and a greater proportion of FORCE 1 classification and female sex, which may confound outcome comparisons despite applied adjustments. Missing data at baseline (PROMIS scores) and loss to follow-up (missing discharge CPET) limit the analysis. Satisfaction data were self-reported. Future prospective, randomized trials comparing hybrid and in-person delivery in more complex CHD populations are needed, with attention to long-term adherence, equity of access, and intentional design of the virtual experience.

Conclusion

A hybrid rather than all in-person delivery model for cardiac fitness and rehabilitation is a newer model of care. In a head-to-head analysis, both hybrid and in-person cardiac fitness programs produced meaningful, safe improvements in fitness, strength, flexibility, and mindset in patients with CHD, demonstrating that delivery format does not limit effectiveness or adherence. While the hybrid model demonstrated advantages in mindset outcomes and fitness progression, participants within that group consistently favored their in-person sessions over virtual training. That preference is informative: it suggests that as the field moves toward scalable, technology-enabled rehabilitation, the human element of in-person care retains value. The optimal model for CHD fitness programs may not be a choice between virtual and in-person, but a deliberate integration or offering of both.

Declarations

Author Contribution

TC and NG wrote the main manuscript text and revised it critically for important intellectual content and prepared figures and revised tables.JP , JG and AF assisted with data collection, approved the version to be published and agree to be accountable for all aspects of the work.KG conducted the analysis and prepared tables, and reviewed methods and results critically for accuracy.All authors contributed to the study conception and design.

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Figures

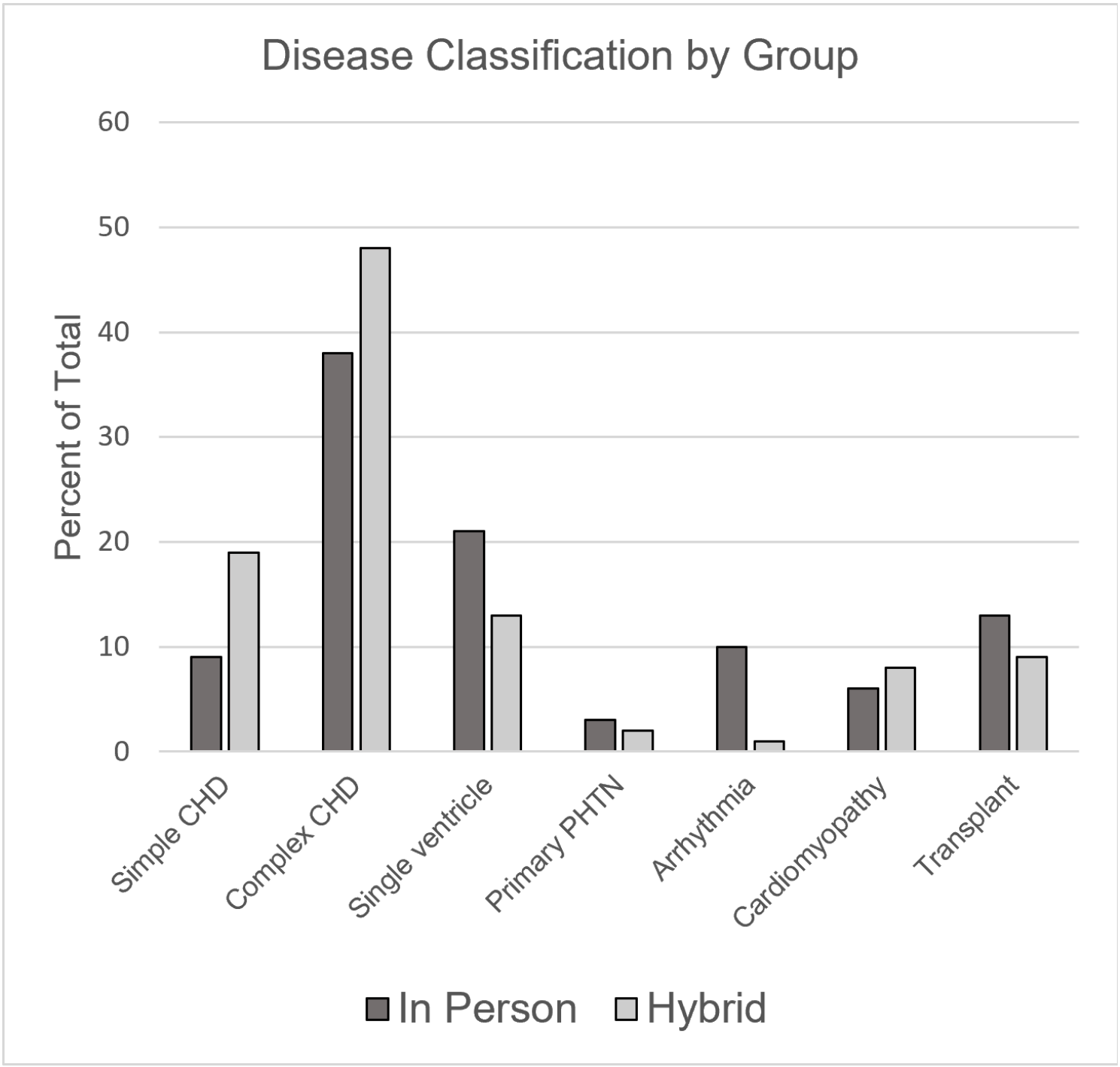

Figure 1

Disease Classification by Group

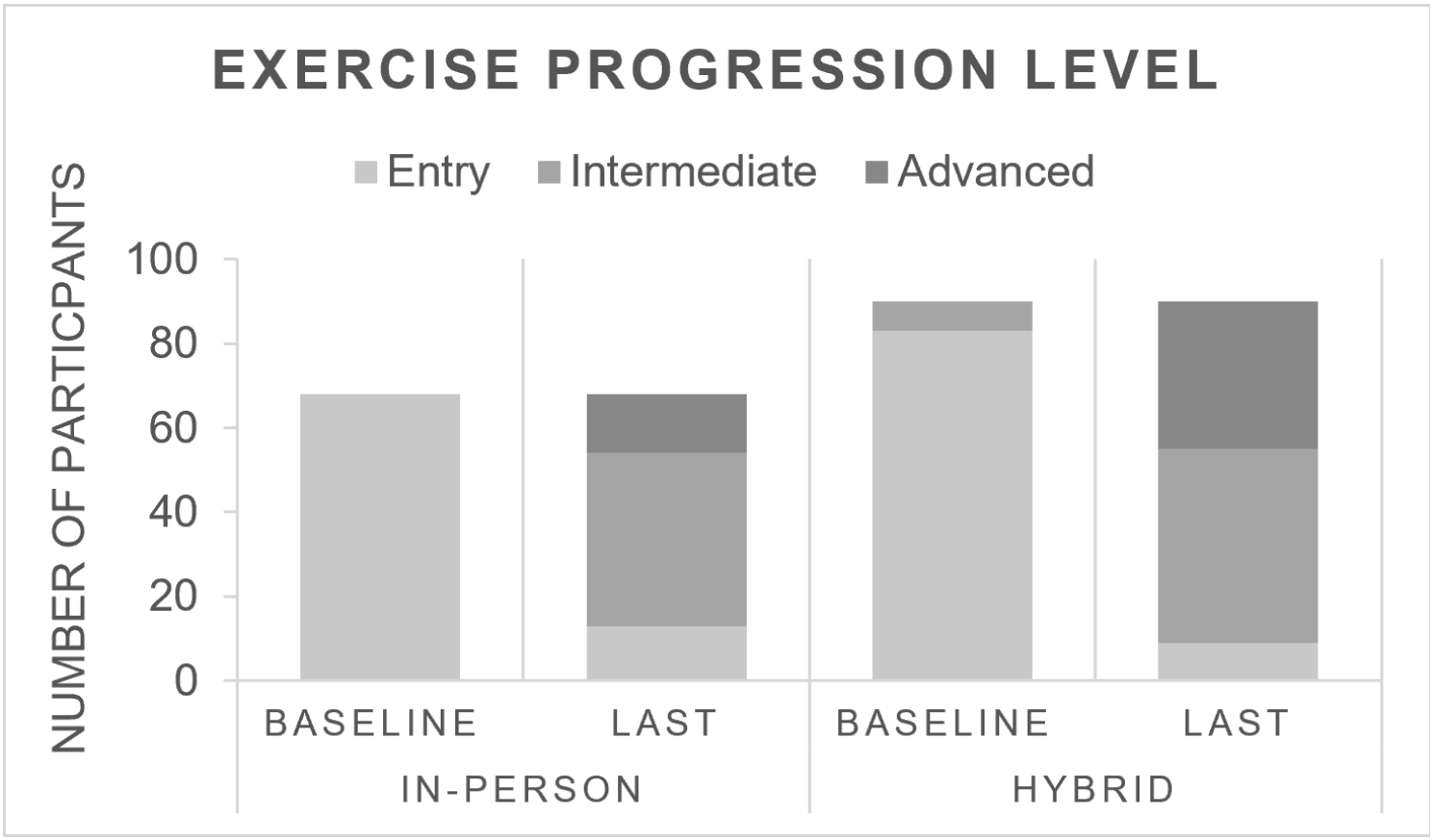

Figure 2

Exercise level at baseline and last follow-up for the two groups