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Clinical and translational science award T32/TL1 training programs: program goals and mentorship practices

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Abstract

Introduction: A national survey characterized training and career development for translational researchers through Clinical and Translational Science Award (CTSA) T32/TL1 programs. This report summarizes program goals, trainee characteristics, and mentorship practices. *Methods:* A web link to a voluntary survey was emailed to 51 active TL1 program directors and administrators. Descriptive analyses were performed on aggregate data. Qualitative data analysis used open coding of text followed by an axial coding strategy based on the grounded theory approach. *Results:* Fifty out of 51 (98%) invited CTSA hubs responded. Training program goals were aligned with the CTSA mission. The trainee population consisted of predoctoral students (50%), postdoctoral fellows (30%), and health professional students in short-term (11%) or year-out (9%) research training. Forty percent of TL1 programs support both predoctoral and postdoctoral trainees. Trainees are diverse by academic affiliation, mostly from medicine, engineering, public health, non-health sciences, pharmacy, and nursing. Mentor training is offered by most programs, but mandatory at less than one-third of them. Most mentoring teams consist of two or more mentors. *Conclusions:* CTSA TL1 programs are distinct from other NIH-funded training programs in their focus on clinical and translational research, cross-disciplinary approaches, emphasis on team science, and integration of multiple trainee types. Trainees in nearly all TL1 programs were engaged in all phases of translational research (preclinical, clinical, implementation, public health), suggesting that the CTSA TL1 program is meeting the mandate of NCATS to provide training to develop the clinical and translational research workforce.

Introduction

The Clinical and Translational Science Award (CTSA) program was begun in 2005 to advance the progress of clinical and translational research (CTR) across many domains [1]. Education and training have been a key component from the beginning. CTSA hubs provide research training and career development programs that impart the knowledge, skills, and approaches required for high-quality translational science, and facilitate the training of scientists from diverse backgrounds underrepresented in translational science. The TL1 and KL2 CTSA-linked programs are complementary institutional awards that focus on the research training and career development of pre- and postdoctoral trainees and early-stage translational researchers, respectively [1–7].

What is currently referred to as the "TL1 program" has evolved considerably since 2005, as summarized in Fig. 1A. The first CTSA request for applications (RFA) issued in 2005 included a Predoctoral Research Training National Research Service Award (NRSA) T32 training component as an optional module of the CTSA U54 award to support translational research training for predoctoral students pursuing a PhD or other research doctorate [1]. The RFA was amended to include options for supporting health professional predoctoral students pursuing a combined

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A

Year	Training Award Type	Trainee Types, Numbers of Trainees if Specified, and Training Duration			
		Predoctoral	Postdoctoral	Short-Term	Year-Out
2005[1,2]	T32 component	• PhD or other research doctorate • Four trainees • 3 years	• No	• Health professional students • 2-3 months	• Combined research masters with health professional degree • 1+ years
2008[3,4]	T32 component	• Number of trainees no longer specified • 3 years	• Added postdoctoral trainees • 1+ years	• 2-3 months	• Added 12-month research training rotations for health-professional trainees
2009[5]	TL1 component	• Changed to 1+ years	• 1+ years	• 2-3 months	• 1+ years
2014[6]	TL1 award	• 1+ years	• 1+ years	• 2-3 months	• 1+ years
		• Number of trainees specified as 10/15/20 for small/medium/large CTSA hubs, respectively			
2018[7]	TL1 award	• 1+ years	• 1+ years	• 2-3 months	• 1+ years
		• Budget capped at $400K/$600K/$800K for small/medium/large CTSA hubs, respectively			

B

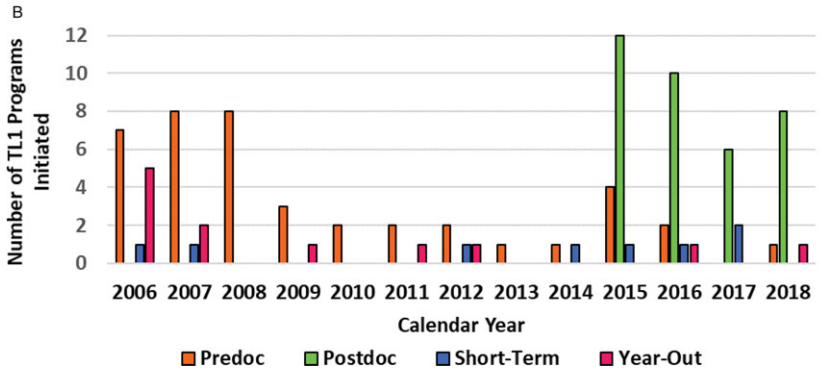

Fig. 1. CTSA T32/TL1 Program Evolution and Growth. A. Major programmatic changes of the Clinical & Translational Science Award (CTSA) T32/TL1 program. **B.** Number of TL1 programs supporting each of the TL1 trainee types that were initiated during each calendar year (2006-2018) at CTSA institutions.

clinical research master's degree or participating in short-term clinical research experiences ranging from two to three months [2]. The option of offering special 12-month year-out research training rotations to provide health professional predoctoral level trainees with practical experience in clinical research was added in 2008, [3] and the 2009 RFA added the option of supporting postdoctoral trainees [4]. Predoctoral training in this RFA emphasized fundamental research training in clinically related areas of biomedical and behavioral sciences, and postdoctoral research training emphasized specialized training corresponding to the interests of NIH Institutes and Centers. The NRSA training component was designated as TL1 in the second RFA in 2009 [5].

The 2014 funding opportunity announcement (FOA) introduced changes designed to increase the impact of CTR in response to a report by the Institute of Medicine (IOM), encouraging innovative curricula with team-based education and training, preparation for multidisciplinary research, training in rigorous research methodology, non-traditional research experiences outside the home institution, more focus on core competencies rather than formal degrees, and flexibility to adapt to individual training needs [6]. The FOA realigned the CTSA mission in response to the IOM report and established the NRSA Training Core as a separate optional TL1 training grant award linked to the parent CTSA award [6]. The types of training that could be offered were all optional and adaptable to individual trainee needs, including predoctoral (PhD and dual degree), postdoctoral, short-term, and year-out research training. There was better alignment with overall CTSA program goals, with additional emphasis on human health- and disease-related research training, rigorous research methodology, career and professional development, usage of Individual Development Plans (IDPs), training in team science, cross-disciplinary training approaches, and translational research core competencies.

By 2015, approximately fifty CTSA hubs had NRSA training programs (hereafter referred to as TL1 programs). Given the evolution and heterogeneous training components implemented by individual CTSA hubs, the CTSA Workforce Development Enterprise Committee conducted a national hub-reported survey of TL1 programs to determine the breadth of services offered, develop a snapshot of trainee characteristics and program goals, and identify contemporary practices. This report summarizes overall and distinguishing TL1 program goals and trainee characteristics, as well as mentorship practices for predoctoral and postdoctoral trainees. Trainee selection practices, curriculum content, and evaluation methods used by TL1 programs will be reported separately.

Methods

The TL1 survey was conducted under the aegis of the National Center for Advancing Translational Sciences (NCATS) Workforce Development Enterprise Committee (formerly known as the Translational Workforce Development Domain Task Force), a group that was established to promote high-impact educational practices for trainees and scholars pursuing CTR careers. In 2018-19, members of the Working Group (WG) on Best

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Practices for Mentoring and Supporting TL1 and KL2 Programs designed and implemented a survey of TL1 leaders (Program Directors and administrators) regarding TL1 program structures and practices, as well as trainee characteristics and outcomes. Due to the parallel nature of TL1 and KL2 programs, the TL1 survey utilized a similar format as the previously published CTSA KL2 survey [8].

After extensive input from both Workforce Development leaders and TL1 Program Directors as to survey content and administration, the final version was constructed in REDCap with branch logic to accommodate the four diverse TL1 trainee types that could be supported. The trainee types were defined as *Predoctoral* – PhD and dual degree-seeking students; *Postdoctoral* – postdoctoral fellows; *Short-Term* – health professional students in short-term programs, for example, summer research programs; and *Year-Out* – health professional students in combined master's degree programs or one-year non-degree programs. The survey contained a combination of single-and multiple-response items, Likert scales, data tables, and short open-text response questions. A penultimate survey draft was circulated to eight TL1 Program Directors and their administrative teams, who beta-tested the draft and provided critical feedback that informed a revised final survey. Throughout the survey development process, the WG sought to balance obtaining a rich data set against overburdening survey respondents. The survey was reviewed by the University of Rochester Institutional Review Board and determined to be exempt from the requirements of the Code of Federal Regulations.

A web link to the final voluntary survey (Supplemental Table 1) was emailed in April 2019 to TL1 Program Directors and administrators at 51 TL1 programs associated with 60 CTSA awards in fiscal year 2019. Three reminders were sent to encourage completion, and the survey was closed in December 2019. Data from responsive CTSA hubs were collected and managed using REDCap electronic data capture tools hosted at the University of Rochester Center for Leading Innovation and Collaboration (CLIC) [9].

Survey data were exported from REDCap to an Excel spreadsheet. Descriptive analyses were performed on aggregate data from all responding CTSA hubs. To maintain anonymity of responses during data analysis, responding CTSA hubs were identified only by a randomly assigned hub number. Several questions invited text responses for qualitative data analysis. Institutional identifiers were redacted from text responses prior to qualitative data analysis. After establishing a general framework for qualitative data analysis (open coding of text related to initial domains of interest), an axial coding strategy based on the grounded theory approach [10] led to specific categories, following procedures that the authors have used previously [11–14]. Two experienced coders independently assigned initial codes to each text response; a third individual served as an adjudicator. Inter-rater reliability prior to adjudication was assessed using the simple proportion agreement method rather than a more complex statistic due to the relatively large number of cases, the possibility for multiple codes within text units, and the exploratory nature of this study [15]. Data for all trainee types are presented together to allow holistic analysis of TL1 programs and comparisons across trainee types.

Results

T32/TL1 Program Evolution

Based on the calendar years that CTSA T32/TL1 programs were initiated, three phases of program growth were identified (Fig. 1B). The first three years of the CTSA program (2006–2008) were associated with a progressive increase in training programs that supported predoctoral, short-term, and year-out trainees. This phase was followed by six years of slower program growth with the addition of a few new programs each year supporting predoctoral, short-term, and year-out trainees. The last four years included in the survey (2015-2018) were associated with a large expansion of the program due in part to the addition of postdoctoral trainees. Although supporting postdoctoral trainees was an option beginning in the 2009 RFA, [4] survey respondents did not report support of postdoctoral trainees in new awards until 2015, after the 2014 RFA was issued [6]. These historical changes among the TL1 programs align with some of the programmatic adjustments in the CTSA program as described in the successive RFAs (Fig. 1A).

CTSA Program Level Data

Respondent TL1 programs and leadership

Fifty of the 51 invited CTSA TL1 programs responded to the survey request (98% response rate), representing 83% of all CTSA hubs during FY2019. Not all programs responded to every question; thus, the numbers of responses varied for individual survey items. Programs (N = 46) reported that their TL1 leadership was structured as co-directors with complementary skills and responsibilities to those of the contact principal investigator (52%), one primary director who mentors the co-directors for sustainability (30%), or both (18%). Educational degrees of TL1 program leaders varied (N = 49), with 31% reported as MD only, 33% as PhD only, 20% as MD-PhD, and 16% with other degrees, including ACNP, DDS, MPH, PharmD, and RN.

TL1 Program Goals

The two survey questions that addressed the topic of TL1 program goals were "What are stated goals or specific aims of your TL1 program as a whole?" and "Which goals distinguish your TL1 program as a whole from other NIH-funded training programs?" (Table 1). The percent agreement for the coding of responses to each of these open-ended questions was 78% and 97%, respectively.

Not surprisingly, the overall goals of TL1 programs (N = 50) were responsive to the CTSA program announcements summarized in Table 1A. The most common themes mentioned by half or more of the responding programs included clinical and translational science training; collaboration and/or team science; career/professional development; diversity of trainees; and mentoring. Other common themes (26–46% of responses) included multi-/inter-/cross-disciplinary training; new program elements or focus; program evaluation; CTR competencies; and individualized training. Less common themes (14–24%) included collaboration & dissemination; experiential learning; adding new trainee types or expanding access to training; entrepreneurship; responsible conduct of research (RCR) and/or rigor & reproducibility; community engagement; and building a community of clinical and translational researchers.

Survey respondents also identified goals that distinguish their TL1 program from other NIH-funded training programs (Table 1B). The most common themes among the 48 responses (21–42% each) included interdisciplinary approach and CTR focus; CTR training content; integrated training for trainee types and career stages; a specific research focus or emphasis (*e.g.*, regenerative medicine, population health); team science and collaboration; and individualized training. Less common themes (6–19%

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Table 1. *TL1 Program Goals*

A. What are stated goals or specific aims of your TL1 program as a whole? (N = 50 survey responses)		
Theme	***n (% of total)**	**Example**
Clinical & translational science training	40 (80%)	*Rigorous and effective C/T research training across disciplines*
Collaboration and/or team science	40 (80%)	*Best practices in enhancing interdisciplinary team science skills*
Career/professional development	29 (58%)	*Provide innovative and broad-based career and professional development opportunities to build professional skills*
Diversity of trainees	29 (58%)	*Diverse trainee population with respect to clinical background and disciplinary perspective and . . . race/ethnicity, social disadvantages, and disabilities*
Mentoring	28 (56%)	*Dual-mentored training experiences in preclinical and clinical research*
Multi-/Inter-/Cross-disciplinary	23 (46%)	*Inspire careers dedicated to interdisciplinary translational science*
New program elements, focus	22 (44%)	*Implement learning strategies for these students using novel curricula*
Program evaluation	19 (38%)	*Utilize a comprehensive evaluation plan that incorporates quantitative and qualitative data from multiple sources to enhance program improvement*
CTR Competencies	15 (30%)	*Rigorous training that builds core competencies in clinical and translational research*
Individualized training	13 (26%)	*Personalized to the interest and needs of each trainee*
Collaboration & dissemination	12 (24%)	*Pursue regional and national CTSA collaborations for greater innovation & impact*
Experiential learning	12 (24%)	*Immersing them in the actual translation of research products*
Add new trainee types, expand access	12 (24%)	*Create and implement a postdoctoral mentored TL1 training program*
Entrepreneurship	10 (20%)	*New externships in entrepreneurship*
RCR, rigor & reproducibility	7 (14%)	*Engraft principles of responsible conduct of research and the importance of reproducible science*
Community engagement	7 (14%)	*Learner-level appropriate competency in . . . stakeholder engagement*
Build community of C/T researchers	7 (14%)	*Establish and nurture a community of graduate students and faculty*
Other	4 (8%)	*Emphasize the unique regional populations and associated research studies*
B. Which goals distinguish your TL1 program as a whole from other NIH-funded training programs? (N = 48 survey responses)		
Theme	***n (% of total)**	**Example**
Interdisciplinary approach, CTR focus	20 (42%)	*Non-categorical, translational, cross-disciplinary*
CTR training content	11 (23%)	*Focused on integrating clinical and translational science competencies into graduate/medical education*
Integrated training for trainee types	11 (23%)	*Vertical integration across career stages*
Specific focus or emphasis	11 (23%)	*Entrepreneurship*
		Stem cells and regenerative medicine
		Type 3 (health services) and Type 4 (population health) translational research
		Interdisciplinary nature of pediatric/engineering focus
		Medical informatics
Team science, collaboration	11 (23%)	*Didactic and experiential Team Science training*
Individualized training	10 (21%)	*Individualized enrichments in six areas*
Mentoring teams	9 (19%)	*Strong multidisciplinary mentorship*
Multiple institutions, campuses	8 (17%)	*New collaborative efforts to provide training and career development across 3 institutions*

(*Continued*)

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Table 1. (*Continued*)

B. Which goals distinguish your TL1 program as a whole from other NIH-funded training programs? (N = 48 survey responses)		
Theme	***n (% of total)**	**Example**
Diverse trainees, disciplines, underrepresented in medicine & science	7 (15%)	*Diverse disciplines including biomedical science, medicine, nursing, social and behavioral sciences, and engineering*
Other	5 (10%)	*Strong emphasis and focus on career development*
		Special focus on physician-scientists in training
		Translational research grant application … as a required capstone project
Degree/certificate, academic program	4 (8%)	*All trainees are engaged in a formal academic program*
Community engagement	3 (6%)	*Engaging … patient and community stakeholders, at early stages of trainees' research*
Competency-based	3 (6%)	*Translational science competencies-based curriculum*

*n = The number of responses that addressed the corresponding theme.
Abbreviations used: CTR, clinical & translational research; CTSA, Clinical & Translational Science Award; RCR, responsible conduct of research; C/T, clinical and/or translational

each) included mentoring teams; multiple institutions or campuses; diversity of trainees and disciplines; academic programs such as degree or certificates; community engagement; and competency-based training and/or assessment.

Distribution of TL1 Trainee Types

The types and numbers of TL1 trainees supported by CTSA hubs at the time of the survey (N = 48) are summarized in Fig. 2. Grouped according to CTSA award size, there was considerable variation in the types of TL1 trainees supported by each program and in the total number of TL1 trainees per program (Fig. 2A). For example, the CTSA hub represented in the first column reported 16 total trainee slots: four predoctoral, two postdoctoral, and ten short-term. Note that 20 respondents were classified as small, 13 as medium, and 15 as large hubs, as defined by NCATS [5]. The total number of trainee slots per hub ranged from three to twenty. The most common combination of TL1 trainee types was predoctoral plus postdoctoral trainees, reported by 19 of 48 (40%) TL1 programs. Nine programs (19%) supported predoctoral trainees only, whereas four programs (8%) supported postdoctoral trainees only. Other common combinations included five programs (10%) each with predoctoral / postdoctoral / short-term and predoctoral / postdoctoral / year-out. Less common combinations included postdoctoral / year-out, predoctoral / short-term / year-out, postdoctoral / short-term, and short-term / year-out (1–4 programs [2–8%] each). No TL1 programs reported support for all four types of trainees.

The distribution of CTSA-funded cumulative training slots was highly variable for each TL1 trainee type (Fig. 2B). Overall, respondents reported that 285 predoctoral trainee positions were awarded, representing 50% of all TL1 trainees, with an average of 7.3 slots per hub (range 1–16). Respondents reported a total of 170 postdoctoral trainees (30% of all TL1 trainees, 4.6 per hub, range 1–12), 61 short-term trainees (11%, 7.6 per hub, range 4–16), and 53 year-out trainees (9%, 5.3 per hub, range 1–10).

Academic Homes of TL1 Trainees

The academic homes (colleges/schools) of trainees eligible to apply for TL1 funding, trainees who applied for funding, and trainees awarded TL1 funding are summarized in Fig. 3 for all four types of TL1 trainees. Colleges/schools of medicine predominate for all four TL1 trainee types in eligible, applied, and awarded TL1 slots, followed in descending order of prevalence by nursing, engineering, and public health. Although eligible trainees from medicine both apply for and receive TL1 awards, significant gaps exist between eligible and applied trainees and between applied and awarded trainees from other academic homes, especially in nursing, dentistry, public health, and pharmacy. For example, although predoctoral trainees in nursing colleges/schools were eligible to apply for TL1 support at 31 programs, they actually applied at only 17 programs and were awarded support at only 11 programs (Fig. 3A).

Predoctoral TL1 programs were the most inclusive of trainees from a variety of CTSA partner colleges and schools. The majority of 40 predoctoral TL1 programs (93%) supported school/college of medicine trainees; 28–53% of predoctoral programs supported trainees from schools/colleges of engineering, public health, non-health sciences, pharmacy, and nursing (Fig. 3). A small number of predoctoral TL1 programs supported trainees from remaining academic homes (0–18%). Similar to predoctoral programs, nearly all (92%) of the 38 postdoctoral TL1 programs supported medicine trainees; 21–32% of these programs supported trainees from engineering, public health, and nursing. Seven of the eight (88%) short-term TL1 programs supported medicine trainees; 25–50% of these programs supported trainees from nursing, engineering, pharmacy, and non-health sciences. Year-out TL1 programs were the least discipline-inclusive. All eleven year-out TL1 programs supported trainees from medicine, three (27%) supported trainees from nursing, and only one or two (9–18%) supported trainees from engineering, public health, dentistry, non-health sciences, and pharmacy.

Clinical and Translational Research Areas of TL1 Program Trainees

The types of research pursued by TL1 program trainees included basic, preclinical (T0), clinical (T1-T2), implementation (T3), and public health (T4) research (Fig. 4) [16]. The most common types of research were preclinical and clinical (76% each) for predoctoral program trainees, clinical (89%) for postdoctoral program trainees, clinical and implementation (91% each) for short-term program

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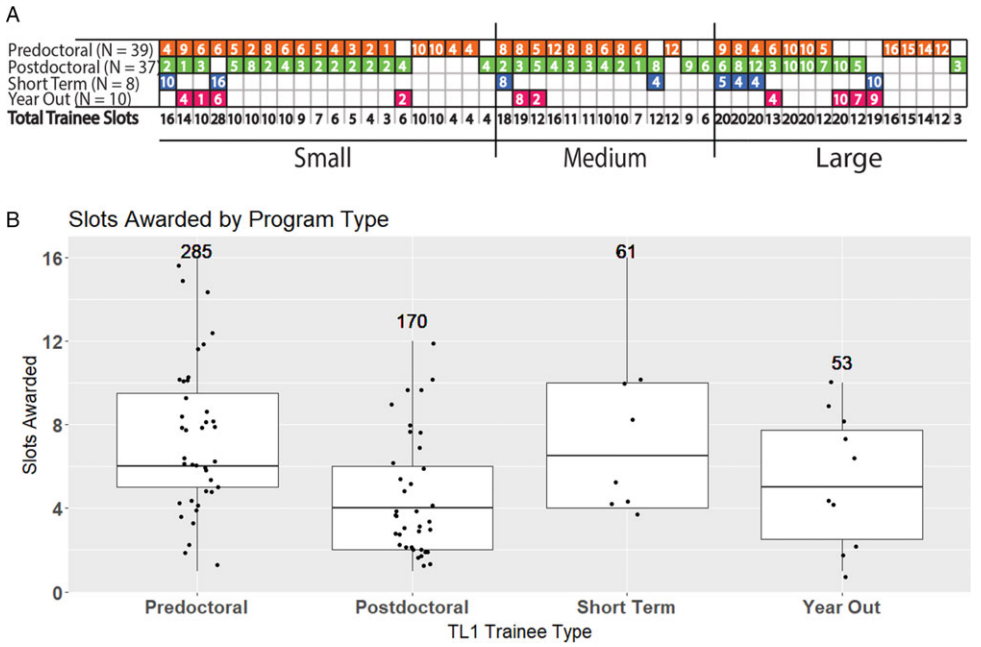

Fig. 2. Current TL1 Trainee Types by Program and Number of Training Slots by Trainee Type. A. TL1 trainee types and number of trainee slots by TL1 program. Each column represents a TL1 program. Filled boxes represent the trainee types (Predoctoral, Postdoctoral, Short Term, and Year Out) supported by each TL1 program. The white numbers represent the number of slots reported by a hub for that trainee type. Total numbers of trainee slots for each hub are reported below each column. Programs are clustered by Clinical & Translational Science Award (CTSA) program size as defined by the National Center for Advancing Translational Sciences (NCATS) [5]. **B.** Distribution of training slots awarded per TL1 program for each TL1 trainee type. Each data point represents an individual TL1 program. The numbers above the box plot represent the total number of slots awarded across all TL1 programs for each TL1 trainee type.

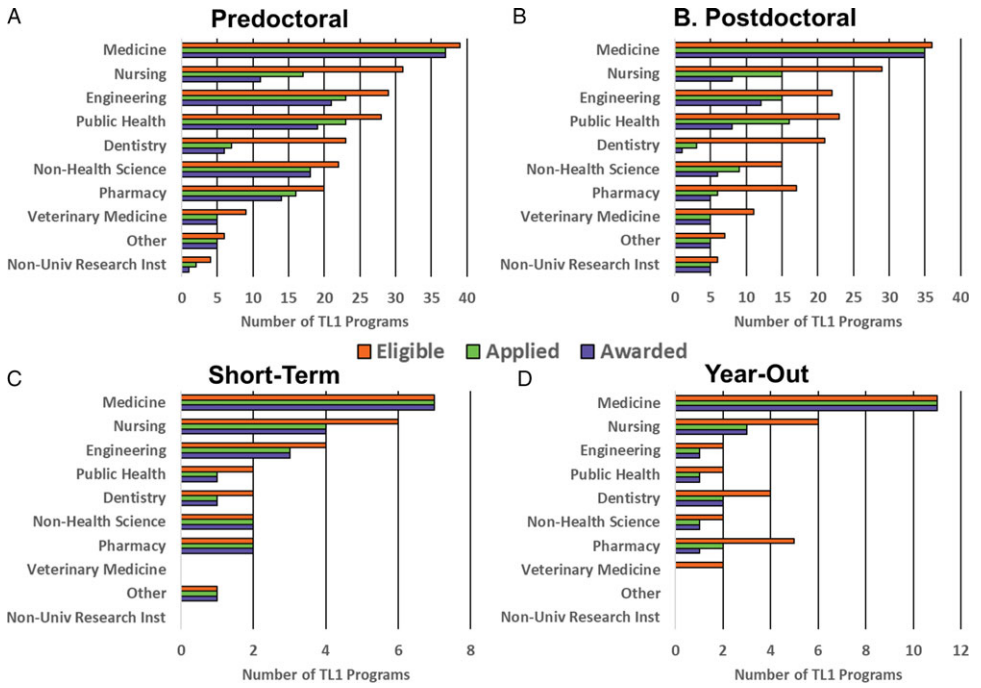

Fig. 3. Academic Home of TL1 Eligible Trainees, TL1 Applicants, and TL1 Awardees. Numbers of TL1 programs with trainees from each academic home (school/college) who were eligible to apply for TL1 funding (orange), applied for TL1 funding (green), and awarded TL1 funding (purple). **A.** Predoctoral programs (N = 40). **B.** Postdoctoral programs (N = 38). **C.** Year-Out programs (N = 8). **D.** Short-Term programs (N = 11). Abbreviation used: Non-Univ Research Inst, Non-University Research Institute.

trainees, and clinical and public health (88% each) for year-out program trainees.

Among all TL1 programs, the types of research performed by TL1 trainees appeared as four patterns (Fig. 4B). The most common pattern was a focus on translational research training only for predoctoral (48%), postdoctoral (57%), short-term (38%), and year-out (73%) TL1 programs. The second-most common patterns (9–38% of TL1 programs) were trainee engagement in basic research and some or all phases of translational research. The least common pattern of research by TL1 trainees

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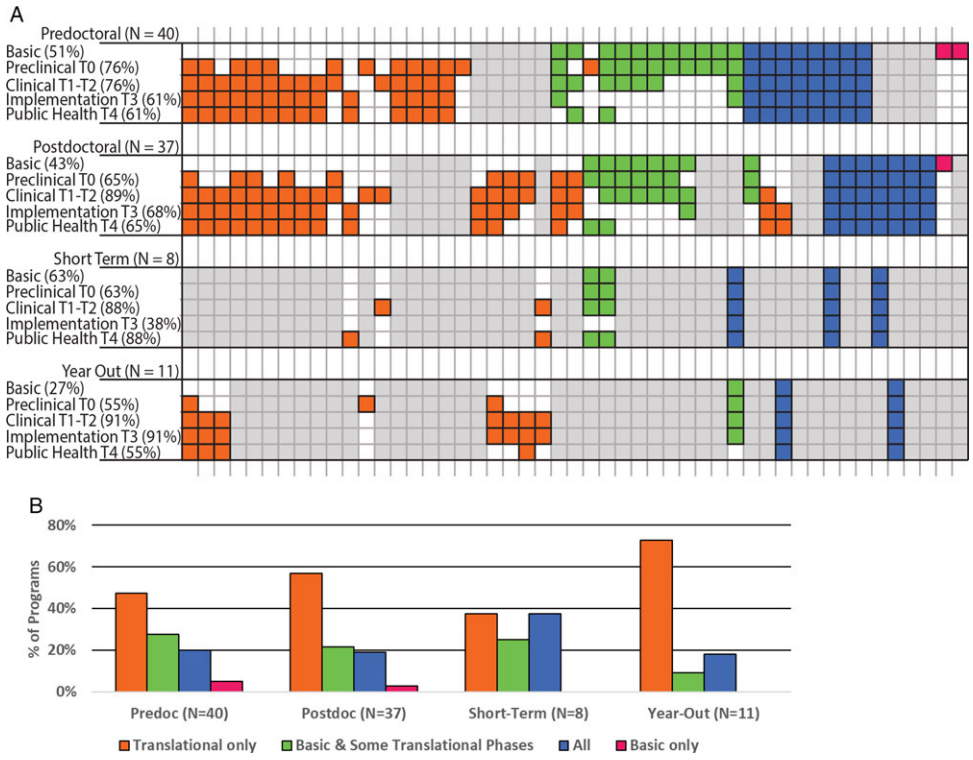

Fig. 4. Distribution of Types of Translational Research in TL1 Programs. A. Each column represents a TL1 program (programs are not in the same order as in Fig. 1). Filled boxes indicate that TL1 trainees are engaged in basic, preclinical (T0), clinical (T1-T2), Implementation (T3), and/or public health (T4) research. Gray boxes indicate absence of trainee type. Other colors correspond to four patterns of research, summarized in part B. **B.** Percentage of programs with TL1 trainees engaged in any combinations of translational research (T0-T4) only (orange), basic research plus some, but not all, phases of translational research (green), basic research plus all phases of translational research (blue), and basic research only (red).

was basic research only (0–5%). Only two CTSA hubs support predoctoral and/or postdoctoral TL1 trainees conducting basic research only, with no year-out or short-term trainees reported to be conducting basic research only.

Mentorship Training in TL1 Predoctoral and Postdoctoral Programs

Program directors and administrators were asked to briefly describe the format of the mentorship training available for TL1 mentors and for CTSA-funded TL1 trainees in predoctoral and postdoctoral programs. The percent agreement for the coding of mentor and mentee training responses across programs was 78% and 69%, respectively.

The majority of CTSA hubs with TL1 predoctoral programs (90.2%) offered mentor training, though only 19.5% reported this training as mandatory (Fig. 5A). For TL1 postdoctoral training programs, 83.8% of hubs offered mentor training, with 29.7% requiring this training for research mentors. Most mentor training was delivered in the format of workshops and seminars, though other modalities, such as online formats or the University of Wisconsin-Madison "Entering Mentoring" program [17–18], were also reported (Fig. 5B). Of all CTSAs offering TL1 support to predoctoral and postdoctoral trainees (n = 37), 31 hubs (83.8%) had available mentor training for both TL1 program types (data not shown). From qualitative responses such as "see postdoctoral survey response," we inferred that at least seven of these 37 CTSAs with more than one TL1 trainee type were offering the same training to the mentors of trainees across career stages.

In addition to mentor training, CTSA hubs with predoctoral and postdoctoral TL1 programs also provided mentorship training to their mentees. Most CTSA hubs have mentee training available for predoctoral and postdoctoral programs (78.1% and 75.6%, respectively). However, only 22% of hubs with predoctoral programs and 32.4% of hubs with postdoctoral programs reported this training as mandatory (Fig. 5C). Like mentor trainings, most mentee trainings are delivered as workshops and seminars, such as case study-based programming. Other types of trainings are noted in Fig. 5D. While they mostly parallel the mentor training offerings, there are some hubs that incorporated their mentee training into course curricula.

Mentorship Practices in TL1 Predoctoral and Postdoctoral Programs

The majority of CTSA hubs with predoctoral TL1 programs reported an average size of trainee mentor teams of two or more (92.6%; Fig. 6A). Most postdoctoral training programs (94.4%) also reported average mentor team sizes of two or more (Fig. 6B). Predoctoral programs reported more frequent mentor team meetings with trainees than did postdoctoral programs (Fig. 6C).

IDP in TL1 Programs

The IDP is a required component for NIH-supported research training programs [19]. Most predoctoral and postdoctoral TL1 programs reported that trainees contributed to their IDPs with mentors or with mentors and program directors (Fig. 7A). Of note,

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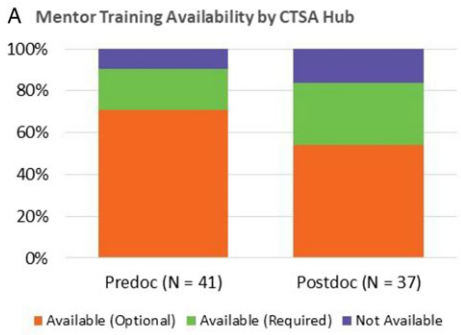

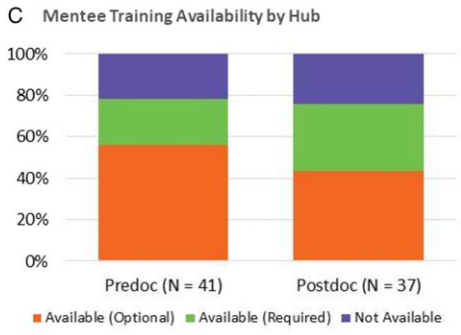

B **Mentor Training Offered**	*n (% of responses)*	
Theme	*Predoctoral*	*Postdoctoral*
Workshops/Seminars	25 (73.5%)	12 (40%)
Online Training	8 (23.5%)	8 (26.7%)
Training as Dyads or Triads	1 (2.9%)	1 (3.3%)
Mentor & Mentee meet with Program Director	1 (2.9%)	1 (3.3%)
Univ. of Wisconsin Program	1 (2.9%)	8 (26.7%)
Mentor Academy, Master Mentor	5 (14.7%)	3 (10%)
Other	0	6 (20%)
Hubs Reporting (N)	**34**	**30**

D **Mentee Training Offered**	*n (% of responses)*	
Theme	*Predoctoral*	*Postdoctoral*
Workshops/Seminars	20 (60.6%)	15 (62.5%)
Online Training	1 (3.0%)	1 (4.2%)
Training as Dyads or Triads	2 (6.1%)	1 (4.2%)
Meetings with leadership	2 (6.1%)	1 (4.2%)
Univ. of Wisconsin Program	6 (18.2%)	5 (20.8%)
Taught as Part of Course	4 (12.1%)	2 (8.3%)
Other	5 (15.2%)	2 (8.3%)
Hubs Reporting (N)	**33**	**24**

Fig. 5. CTSA Hub Mentorship Training. A. Mentor training availability and requirements at Clinical & Translational Science Award (CTSA) hubs by program. Percentages are out of total N hubs reporting. **B.** Summary of qualitative analysis of mentor trainings across CTSAs by program type and example quotes for each code. Note that percentages do not add up to 100% as some responses were coded with multiple categories. **C.** Same as A except for available mentee training. **D.** Same as B except for available mentee training.

however, there were CTSA hubs that reported only the trainee as contributing to the IDP; a few also reported only the mentor or Program Director contributing to the IDP with no input from the trainee.

IDPs were used by TL1 programs (Figs. 7B and 7C) mainly to measure trainee progress (80.5% predoctoral and 81.1% postdoctoral), set milestones (70% of predoctoral and postdoctoral hubs), and provide opportunities for "midcourse" corrections in the training (63.4% predoctoral and 67.6% postdoctoral). TL1 programs also reported using IDP completion as a program metric (43.9% predoctoral and 56.8% postdoctoral). For the few TL1 programs reporting an "other" use for the IDP, responses ranged from being used as a career planning tool or to "identify opportunities," to comments about trainees' dislike for the tool or it being used optionally and variably depending on the mentor team. IDPs were not utilized for any of the stated purposes by 7.3% of predoctoral or 10.8% of postdoctoral TL1 programs.

Discussion

TL1 programs are a NCATS-sponsored research training mechanism to prepare a well-trained workforce that understands the spectrum of translational science needed to move discovery into application and health improvement. This was the first CTSA-wide survey to gather information from TL1 Program Directors and administrators regarding program policies and procedures since the inception of CTSA T32/TL1 programs in 2006.

Survey results demonstrate both TL1 program similarities and variabilities across CTSA hubs. TL1 directors are grounded by health professional (mostly medicine) and/or graduate training, as well as their commitment to share leadership with co-directors that can complement and/or enhance workforce training and facilitate the transition of program leadership when needed. Such practices are consistent with strong academic mentorship for leadership sustainability. Most applications and awards across trainee types are from schools/colleges of medicine, but do include many other health science disciplines, especially for awards to predoctoral and postdoctoral trainees. Such practices acknowledge the valued contributions of CTSA institutional partners and collaborators, and contribute to scientific diversity of trainees. Eighty percent of CTSA-funded TL1 slots were awarded to predoctoral and postdoctoral trainees. As anticipated, there were differences in the number and distribution of awarded slots by the size of CTSA hub. We therefore used data from these two largest program types to describe the variability of TL1 program goals, CTR focus areas, and select trainee practices.

The stated goals of TL1 programs are aligned with the CTSA Training Core review criteria, such as preparing trainees for successful careers as translational scientists, using appropriate inter- or multidisciplinary research training and team-based research opportunities, recruiting diverse trainees across multiple disciplines ranging from basic science to social science including medicine and allied health fields, offering novel learning models to meet the needs of trainees, and reflecting institutional strengths. As summarized in Table 1, the ten most common goals of TL1 programs emphasized training in clinical and translational science; training in a collaborative team science environment; career and professional development of trainees; diversity of trainees based on disciplinary expertise, clinical background, and underrepresented status; effective mentoring; career development for cross-disciplinary research; implementation of new program training elements or focus based on institutional strengths; training program evaluation; CTR competencies; and individualized training.

Most importantly, TL1 programs are distinct from other NIH-funded training programs in their CTR focus. TL1 training crosses

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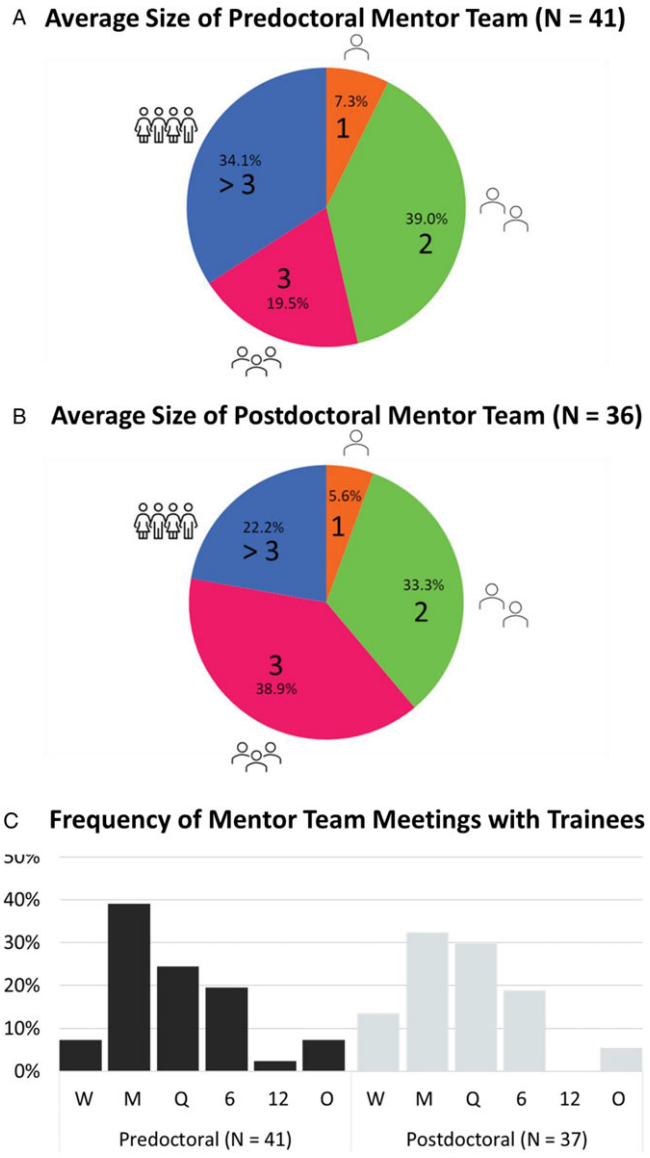

Fig. 6. TL1 Program Mentorship Practices. A-B. Average mentor team size for predoctoral (A) and postdoctoral (B) TL1 trainees. Percentage of TL1 Programs out of the total N that reported an average size of mentor teams of 1, 2, 3, or greater than 3 mentors in their programs. **C.** Frequency of mentor team meetings with the trainee. (W) at least once per week; (M) at least once per month; (Q) at least once per quarter; (6) at least once every six months; (12) at least once every year; (O) other.

all health-related disciplinary boundaries, emphasizing cross-disciplinary research approaches and team science. Training for team science and cross-disciplinary collaboration includes both didactic and experiential training. Many TL1 programs offer vertically integrated training across career stages, including predoctoral (PhD and health professions) and postdoctoral trainees. Many TL1 programs also align CTR training with institutional strengths, such as a focus on entrepreneurship, specific research topics (*e.g.*, regenerative medicine), specific phases of translational research (*e.g.*, health services research or population health), or biomedical informatics.

TL1 programs have addressed the CTSA focus to support graduate and postdoctoral training programs to meet institutional and career development needs across the full spectrum of clinical and translational science research. Ninety-five percent of predoctoral programs and 97.3% of postdoctoral programs reported that trainees conduct research in one or more translational research phases. CTSA hubs are therefore meeting the intention of the NCATS FOAs in providing resources to create an academic home for translational research and providing trainees with CTR-aligned curricula, innovative career development components, and advanced research experiences. The TL1 program is succeeding in training a "disease-agnostic" biomedical research workforce that is distinct from that of most T32 programs, which focus on discipline-specific or disease-focused basic or preclinical research training. Trainees in nearly all TL1 programs are engaged in CTR, suggesting that the CTSA TL1 program is meeting the mandate of NCATS to provide training to develop the CTR workforce.

We focused our analysis of mentoring practices on predoctoral and postdoctoral trainees because they are the majority of learners funded by respondent TL1 programs. Although most programs *offer* training to mentors and mentees, the majority do not *require* mentorship training. The 2014 NCATS RFA [6] was the first to include "Is there a formal or informal mentor training program?" as one of the Mentored Career Development and NRSA Training Review Criteria. To be responsive, training hubs are implementing a variety of trainings, such as seminars and evidence-based workshops, across various platforms (in-person, online synchronous, and online asynchronous) [20–22]. As noted in the survey responses, some CTSA programs have established comprehensive mentoring academies to provide resources for their health sciences faculty [23–24].

However, there is now an opportunity for hubs to embrace the evidence-base and national momentum to require mentorship training in all TL1 programs. Ensuring that everyone attends training provides a baseline level of mentorship skills and confidence on the mentor side [20] and increases the learning gains of trainees participating in training [25]. The NIH scientific approach to inclusive excellence outlined by Dr Valantine called on NIH-funded institutions to develop and prioritize integrated, system-targeted efforts as foundational components of a well-supported, productive workforce, with mentoring noted as a key component [26]. In that regard, our qualitative survey data indicated that TL1 programs offer the same training to mentors of both predoctoral and postdoctoral trainees, a model that can be adopted by hubs that currently do not offer mentor trainings for all programs.

Additionally, the National Institute of General Medical Sciences (NIGMS) Predoctoral Institutional Research Grant (T32) requires applicants to describe how participating faculty are "trained to ensure the use of evidence-informed teaching, training, and mentoring practices that promote the development of trainees from all backgrounds, for example, trainees from groups underrepresented in the biomedical sciences." [27] Similarly, the NIGMS Medical Scientist Training Program instructs applicants to address how the participating faculty: (1) receive training in effective, evidence-informed teaching and mentoring practices; (2) demonstrate a commitment to effective mentoring, and to promoting inclusive, safe, and supportive scientific and training environments; and (3) are evaluated as teachers and mentors [28]. Requiring competency trainings, as well as recognizing and rewarding mentoring, are recommendations to improve research trainee mentorship experiences highlighted in the 2019 National Academies of Science, Engineering, and Mathematics (NASEM) Consensus Study Report [29].

The NASEM report also outlined the importance of mentoring teams and networks that cater to the diversity of mentees' needs [29]. CTSA hubs supporting both predoctoral and postdoctoral trainees reported that most TL1 mentor teams were composed

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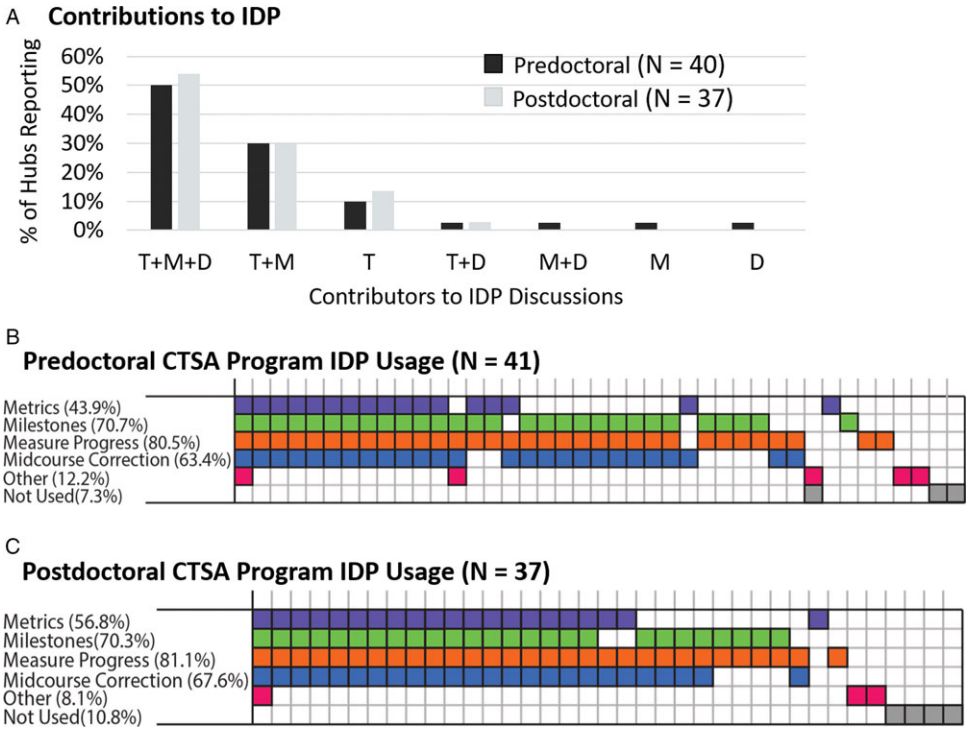

Fig. 7. Individual Development Plans (IDP) in TL1 Programs. A. Percentage of Clinical & Translational Science Award (CTSA) TL1 programs reporting the different combinations of Trainee (T), Mentor (M), and Director (D) contributing to the trainee's individual development plan (IDP). **B.** Usage of IDPs by predoctoral trainees at individual TL1 programs. Each column represents an individual predoctoral training program. **C.** Usage of IDPs by postdoctoral trainees at individual TL1 programs.

of two or more people, aligning with these recommendations. Less than 10% of hubs reported an average team size of only one mentor (for both postdoctoral and predoctoral trainees). Although most hubs reported that mentor teams met with their trainees on a semi-regular basis (monthly to quarterly), we observed a trend towards less frequent meetings with postdoctoral TL1 trainees, suggesting greater independence at the postdoctoral stage and a reduced need for frequent meetings.

IDPs are tools that provide structured reflection for trainees and mentors to discuss learner strengths and areas in need of growth related to career aspirations [19]. These tools provide trainees, mentors, and Program Directors with an opportunity to intentionally reflect and engage in dialogue on a regular basis. IDPs have become more common since the NIH began to strongly encourage their use and require data in annual progress reports [19]. IDPs are, by design and definition, used to provide a plan, framework, and opportunity to discuss the career plans of the trainee. Perhaps somewhat unsurprisingly, our data show most TL1 programs report contributions from trainee, mentor, and Program Director to trainees' IDPs. The second-most common grouping for IDP contributions were trainees and their mentors. Most surprisingly, however, a few hubs reported only *one* person contributing to the IDP, the trainee, mentor, or Program Director.

TL1 programs use the IDP for a wide range of purposes, from program metrics, to creating milestones, and measuring trainee progress, suggesting a versatility to the tool that goes beyond its original conception. It should be noted that NIH does not mandate how training programs choose to implement or use the IDP, only that its use be reported. Whether TL1 trainees would benefit from standardized IDP use across CTSA hubs is currently under investigation (D. Rubio, personal communication). However, there are opportunities for growth and change. In particular, the small number of TL1 programs not involving trainees in the IDP process can reassess their goals for IDP use and realign practices to be more in accordance with the original IDP's design.

Limitations

We acknowledge the inherent limitations of hub-reported aggregate data that rely on retrospective recall, supplemented by program files, records, and annual reports to complete this survey. We appreciated the efforts of the CTSA TL1 program teams that resulted in a 98% response rate. Thus, we consider these data to be representative of TL1 programs nationally, enabling the workforce community to contrast this program with other NIH training and career development opportunities such as the NCATS intramural program [30] and the NIH institute-specific T32 training grants.

Conclusions and Future Directions

These survey results provide evidence that the TL1 program is a unique and innovative career development approach to prepare a workforce capable of advancing translational science across the diverse translational research spectrum. The CTSA T32/TL1 program has undergone remarkable evolution since its inception in 2006, supporting predoctoral, postdoctoral, short-term, and year-out trainees. Training goals are aligned with the CTSA mission, focusing on CTR training in cross-disciplinary, collaborative settings. CTSA T32/TL1 programs are distinctly different from other NIH-funded training programs due to their CTR focus, cross-disciplinary approaches, emphasis on team science, and integration of multiple trainee types.

CTSA T32/TL1 programs have the flexibility to meet the needs of its diverse trainees, who are affiliated with a wide range of

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disciplines engaged in health-related research and are engaged in all phases of translational research. CTSA institutions align training programs with institutional strengths, resources, and experiential learning. A companion report will detail trainee selection processes, curriculum content, and evaluation methods. The opportunities to support multiple trainee types (predoctoral, postdoctoral, short-term, and year-out) allow CTSA institutions to meet local training and career development needs and to build capacity at different career levels. One aspect of training that should be strengthened is mentoring. Although most programs offer mentorship training and use IDPs, trainees would benefit from the implementation of more evidence-based mentoring practices [29].

These survey data of the CTSA T32/TL1 programs are timely. The NCATS Advisory Council approved recommended changes that will lead to the next phase of evolution for the CTSA T32/TL1 program [31]. New FOAs have replaced the TL1 funding mechanism with three optional CTSA award components, including an NRSA predoctoral training grant (T32) that may support predoctoral and year-out trainees [32], an NRSA postdoctoral training (T32) [33], and a Research Education Grants Program (R25) to support short-term trainees [34]. TL1 survey results suggest that CTSA hubs have built a strong foundation to continue preparing trainees to advance diagnostics, therapeutics, clinical interventions, and behavioral modifications that improve health. Although current CTSA TL1 programs are well-poised to be competitive for T32 and/or R25 awards, to be responsive to both training program faculty requirements and scored review criteria, programs must strengthen mentorship through the use of evidence-informed mentoring practices, evidence-informed mentor training, assessment of mentoring behaviors, and monitoring of mentoring behaviors [32, 33].

The ultimate impact of the TL1 program will require analysis of long-term trainee outcomes. Unlike career development programs that fund early-stage investigators, variability in the duration of training for graduate students, postdoctoral trainees, and clinical fellows complicates the full understanding of the scientific and health impact of these unique individuals. We recommend that structured alumni surveys, including key impact metrics (*e.g.*, career progression and satisfaction, grants and publications, mentoring activities), be considered every five years, in conjunction with concurrent surveys of training program directors. Data from public resources such as NIH RePORT and NIH grants databases should also be queried to complement the same five-year reporting periods. Other mechanisms to inform career choices in biomedicine by institutional transparency in reporting graduate student and postdoctoral outcome data, such as the Coalition for Next Generation Life Science, should also be advanced [35–36]. Investment in such tracking activities will help ensure that CTSA T32/TL1 training programs continue to prepare a workforce capable of advancing translational science and human health.

Supplementary material. For supplementary material accompanying this paper visit https://doi.org/10.1017/cts.2021.884

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Disclosures. The authors have no conflicts of interest to declare.

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