



Science and technological innovation in health in Cuba: results in selected problems*

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ABSTRACT

In Cuba, health research is based on the priorities of national scientific policy, derived from the health status of the population. The objective of this article is to describe the characteristics of the Science and Technological Innovation System and how the results of its research benefit the health of population groups. To this end, research related to the generation of products and technologies, diabetes, dengue and disability was selected. This system follows a methodology outlined by the Ministry of Science, Technology and the Environment, and has 37 research entities. It is organized into programs and projects that support basic and applied research using a multidisciplinary and intersectoral approach; these programs and projects are funded mostly by the State and are organized as a closed-loop system, i.e., the same entity is responsible for the entire process, from research to marketing, including market studies and post-marketing monitoring. The selected research projects demonstrate the alignment between research, generalization of results, and their effect in improving the population's health and universal access to health care. Results were obtained in diagnostic methods, preventive and therapeutic vaccines, warning signs for the prognosis and treatment of dengue, prevention of congenital malformations, and policies and programs that have benefited people with disabilities and their families. The State's commitment to developing and funding scientific research, taking intersectoral action, identifying research priorities, and providing systematic training and attention to human resources have been key factors in meeting the system's objectives.

Keywords

National science, technology and innovation policy; health sciences, technology and innovation management; biomedical research; health programs and plans; research design; Cuba

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The Science and Technological Innovation System in Cuba is overseen by the Ministry of Science, Technology and the Environment (CITMA), in accordance with Resolution No. 44/2012, which resulted in the reorganization of scientific activity based on a policy aimed at achieving greater efficiency and closer ties with

productive and service activities (1). Consequently, the number of research programs and structures was reduced, and they were renamed and classified according to their mission as follows (2):

- Research centers, when their main activity is scientific research and innovation;

- Science and technology service centers, in charge of service delivery, specialized production and research;
- Development and innovation units, organized as enterprises,⁶ budgeted units (funded by the State) or other types of organization, all of which are mandated to develop or innovate in order to add value to the goods, services and processes they offer.

Research and development activities are organized on the basis of programs and projects (basic research unit), and are classified as follows (1):

- Projects associated with science, technology and innovation programs designed to study problems of national interest, supervised by CITMA regardless of sector; programs group together interrelated projects to fulfill State priorities; management units in the health sector are responsible for health-related programs
- Projects not associated with programs, aimed at resolving national priorities that do not require implementation of a program
- Institutional projects, which conduct research on priorities identified by non-entrepreneurial entities for solving concrete problems
- Entrepreneurial projects, which aim to solve priority problems specific to enterprises or business groups

Approximately 26% of all Cuban scientific institutions are dedicated to health-related research, development and innovation, and are part of the Ministry of Public Health (MINSAP), the Biotechnology and Pharmaceutical Industry Group (BioCubaFarma), universities and other sectors (4). MINSAP sets the sector's priorities in accordance with the country's economic and social policy guidelines (5).

The State provides funding to carry out research, innovation and development programs and projects at all levels. In 2016, 35.4% of the total national science and technology budget was allocated to science and technology in the health sector (6). Other funding sources include businesses, bank loans, international agencies, nongovernmental organizations, donations and cooperative agreements with other countries (1).

⁶ A state enterprise is an entity with its own legal status, created to produce goods and services through efficient administration of financial, material and human resources. It is considered a fundamental link in the economy.

In the 2013 World Health Report, the Director-General of the World Health Organization (WHO) stated, "All countries must be producers as well as consumers of research. (7).

Cuba has systematically worked toward that goal. The Science and Technological Innovation System for Health (SCITS) is singular and all-inclusive, and guided by two principles: the interdependence of education, services and research; and the integration of scientific advances into social practice (8). This approach enables the study of health problems and needs at the three levels of care (primary, secondary and tertiary) with alternative solutions in accordance with a sectoral, intersectoral, multidisciplinary perspective and adherence to local culture (9).

SCITS' present development is due to the government's commitment and priority attention given to research, innovation and development of products and services to meet the population's health needs. Consequently, conditions, resources and human capital formation are guaranteed so that actions developed in SCITS programs and projects contribute to efficiency, equity and the well-being of the population (10).

The purpose of this article is to describe the features of SCITS in Cuba and present research results that illustrate its positive effect on the population's health.

CUBA'S SCIENCE AND TECHNOLOGICAL INNOVATION SYSTEM IN HEALTH

SCITS comprises 37 science and technological innovation institutions: 16 research centers, 3 science and technology service centers, and 18 development and innovation units administered by MINSAP with methodological oversight by CITMA. Scientific societies contribute to its functioning as do other organizations involved with technological innovation for import substitution (e.g., the National Association for Innovation and Rationalization, the Youth Technical Brigades, and the Science and Technical Forum). This system employs more than 20 000 workers in different occupational categories (Table 1). In addition to research, these centers offer undergraduate and graduate courses, and provide specialized services to the public. In line with CITMA's policy, MINSAP analyzed the situation of

science and set research priorities for 2012–2016 in five national programs, based on changes in the population's health status, availability of resources and the need to optimize them (Table 2), explained as follows (11):

Program 1: Health determinants, risks and disease prevention in vulnerable groups. Emergence of new economic actors and income disparities between different social groups—along with a demographic situation marked by low fertility and birth rates, population aging and migration—have imposed a new social/health context on the National Health System (SNS), in which certain social groups may be affected.

Program 2: Organization, efficiency and quality in health systems and services. Given the constraints imposed on Cuba's access to markets under favorable conditions (12) and the global economic crisis, the SNS has been obliged to prioritize and optimize organizational, quality and efficiency processes in order to maintain the sustainability of current services, based on their design and realities.

Program 3: Natural and traditional medicine. The program attempts to preserve culture in health care through integration of traditional and modern natural medicine techniques.

Program 4: Cancer. Cancer is the second-leading cause of death in Cuba. This group of diseases causes approximately 18 and 19 years of potential life lost in women and men, respectively (13). Research focuses on improving prevention, diagnosis, comprehensive care and rehabilitation.

Program 5: Aging, longevity and health. Individuals aged ≥ 60 years account for 19% of the population, and the indicator is trending upward (13), signifying a greater burden on social and health services; research should contribute to attainment of healthy aging.

By the end of 2016, more than 2 000 research projects were underway, mostly in primary and secondary health care institutions; 401 of the studies in the five national programs were more closely linked to the tertiary level and to institutions in Havana, the country's capital. The results helped identify new research priorities for 2017, such as premature mortality and accidents; the need for further research in basic sciences and state-of-the-art medicine (robotics, computer science, nanotechnology); evaluation of

TABLE 1. Science and technological innovation institutions in the health sector by type and mission. Cuba, 2016^a

Type	Total	Institution ^b	Mission
Research centers	16	National Angiology and Vascular Surgery Institute National Institute of Endocrinology and Metabolic Diseases National Hygiene, Epidemiology and Microbiology Institute National Occupational Health Institute Cardiology and Cardiovascular Surgery Institute Gastroenterology Institute Hematology and Immunology Institute Pedro Kourí Tropical Medicine Institute Dr. Abelardo Buch López Nephrology Institute Dr. José Rafael Estrada González Neurology and Neurosurgery Institute National Oncology and Radiobiology Institute National Minimal Access Surgery Center National Medical Genetics Center International Neurological Restoration Center Research Center on Aging, Longevity & Health Carlos J. Finlay Center for Research and Rehabilitation of Hereditary Ataxias	Basic and applied research related to burden of mortality, morbidity, risks and damage to health, according to specialty
Science and technology services centers	3	National Clinical Trials Coordinating Center (CENCEC) National Medical Sciences Information Center Center for State Control of Medicines and Medical Devices (CECMED)	Surveillance and control of clinical trials Research to strengthen the Scientific and Technical Information System and in the field of health information sciences National regulatory agency
Development and innovation units	18	Ernesto Che Guevara Heart Center (Villa Clara) William Soler Children's Heart Center Center for the Development of Social Sciences and Humanities Immunology and Biologics Center Atherosclerosis Research and Reference Center Toxicology and Biomedicine Center (Santiago de Cuba) National School of Public Health Hermanos Ameijeiras Clinical-Surgical Teaching Hospital Juan Bruno Zayas Clinical-Surgical Hospital (Santiago de Cuba) Dr. Gustavo Aldereguía Lima University General Hospital (Cienfuegos) Juan Manuel Márquez University Pediatric Hospital William Soler University Pediatric Hospital Dr. Antonio Luaces Iraola University Hospital (Ciego de Ávila) Ramón Pando Ferrer Ophthalmology Institute Central Pharmacology Laboratory Cerebrospinal Fluid Laboratory Biomedical Research Unit of Villa Clara Experimental Toxicology Unit (Villa Clara)	Research on health and technology systems and services

^a Human resources according to occupational category: 20 171 health professionals.

^b Place: Havana (other location in parentheses).

Source: Created by the authors based on records from the Ministry of Public Health's National Science and Technology Office.

health technologies; and accreditation of quality in health institutions.⁷

The health research process in Cuba follows universal tenets: starting with a problem—and taking into account the socioeconomic environment, health conditions, societal principles and values—a scientific idea is identified; the problem and method are defined; the project is designed and carried out; and the results are evaluated for subsequent introduction and generalization in social practice until the intervention concludes with new questions (14) (Figure 1).

The ethical conduct and methodological rigor of the research are the responsibility of the researchers, principal investigators and institutional directors, advised by scientific councils and

research ethics committees (1, 2). At the national level, the Center for State Control of Medicines, Equipment and Medical Devices (CECMED) is responsible for ensuring safety and compliance with ethical regulations in individuals and communities.

Product- and service-related projects (medicines, technologies and programs) are conceived as closed-loop processes.

BioCubaFarma was created in 2012 (15, 16) as a senior management organization under the Council of Ministers, which integrates the research-development-production centers for biotechnology, the pharmaceutical industry and high-tech medical equipment. With 32 companies, 70 production facilities, 10 research centers, 11 research and development units, and one science and technology services center, BioCubaFarma

employs 21 000 workers. It is also part of SCITS. Its objective is to ensure that the SNS has the essential medicines (biotechnology and generic), products, raw materials, vaccines, reagents, diagnostic tools and equipment it needs, in addition to its own lines of research (17, 18) (Table 3).

BioCubaFarma is self-financed and conceives scientific research not only as a producer of knowledge but also as a source of material and financial resources for recouping investments without neglecting its social commitment to public health.

The Cuban population's access to high quality medical care is made possible by the integration of research centers with science and technology services delivery centers, development and innovation units, universities and health care

⁷ Morales I. Science Day inaugural speech, Havana, 15 January 2017.

TABLE 2. National science, technology and innovation programs in health. Cuba, 2012–2016

Program (year of creation)	Management unit	Main lines of research
1. Determinants of health, risks and disease prevention in vulnerable groups (2012)	National Hygiene, Epidemiology and Microbiology Institute	<ul style="list-style-type: none"> • Maternal-child health • Demography (birth rate and aging) • Non-communicable diseases • Communicable diseases • Environment, family and community • Food and nutrition safety • Self-inflicted injury • Mental health
2. Organization, efficiency and quality in health systems and services (2012)	National School of Public Health	<ul style="list-style-type: none"> • Health management and its components: equity; access; efficiency; efficacy; social, community and intersectoral participation • Improving risk management in regulatory functions • Patient quality and safety • Application of information and communication technologies • Satisfaction of health personnel
3. Natural and traditional medicine (2015)	Medical University of Havana	<ul style="list-style-type: none"> • Safety, effect and quality of natural and traditional medicine in chronic non-communicable diseases and primary health care • Clinical trials of these modalities approved by the National Health System • Use of herbal medicines and other approved forms of natural and traditional medicine • Sustainability and feasibility studies of technologies • Evaluation, registry and control of natural products, equipment and procedures used in natural and traditional medicine
4. Cancer (2016)	National Oncology and Radiobiology Institute	<ul style="list-style-type: none"> • New tumor markers and diagnostic and treatment products • Immunology and immunotherapy • Clinical trials with new products or new combinations for treatment • Cervical cancer incidence and mortality in women of childbearing age • Cancer prevention and health education, self-care and warning signs with interventions, from an early age • Evaluation of health technologies in the areas of surgery, radiation therapy, nuclear medicine and medical imaging
5. Aging, longevity and health (2016)	Center for Research on Aging	<ul style="list-style-type: none"> • Biomarkers of normal and pathological aging • Evaluation of physical performance, management of fragility and geriatric syndromes • Diseases associated with aging: risk factors, causes, disease burden, effect, costs, prompt detection, diagnosis and treatment • Disability, dependence, and friendly settings • Treatment and care for older adults, relatives and caregivers

Source: Created by the authors based on reference 11.

institutions. Medicines, services and high-tech products are also accessible to population groups requiring them, without tangible costs and with a positive effect on their health.

Developing human capital

Scientific activity calls for highly qualified personnel committed to solving health problems (10). Training for research begins in undergraduate education, is strengthened through work experience, and reaches the height of current knowledge and specialization in graduate education (in Cuba or abroad) up to the doctorate level (10, 19).

Professional researchers are classified through a system that combines years of experience, professional level and outcomes with annual evaluations that show advances or setbacks in indicators measured individually and institutionally, such as participation in scientific projects and events; publications;

dissertations directed; scientific honors and degrees awarded; and registration of patents, copyrights and introduction of results (19).

At the end of 2016, MINSAP had 3 214 researchers classified as senior researchers (8.5%), associate researchers (21.7%), adjunct researchers (57.6%), and researcher candidates (12.2%). During that year, 224 posts became vacant (due to migration, death or retirement); the analysis shows the lowest percentages of researchers in the senior researcher and candidate groups (20).

Extending research to all health units has posed the challenge of a new “literacy” process (21) for appropriate use of scientific mechanisms and tools, given the need to address difficulties common to all SCITS in the Americas, for example: developing research competencies, achieving conscious and responsible participation of affected communities and other sectors, and validating results by

increasing the number of publications and patents (22).

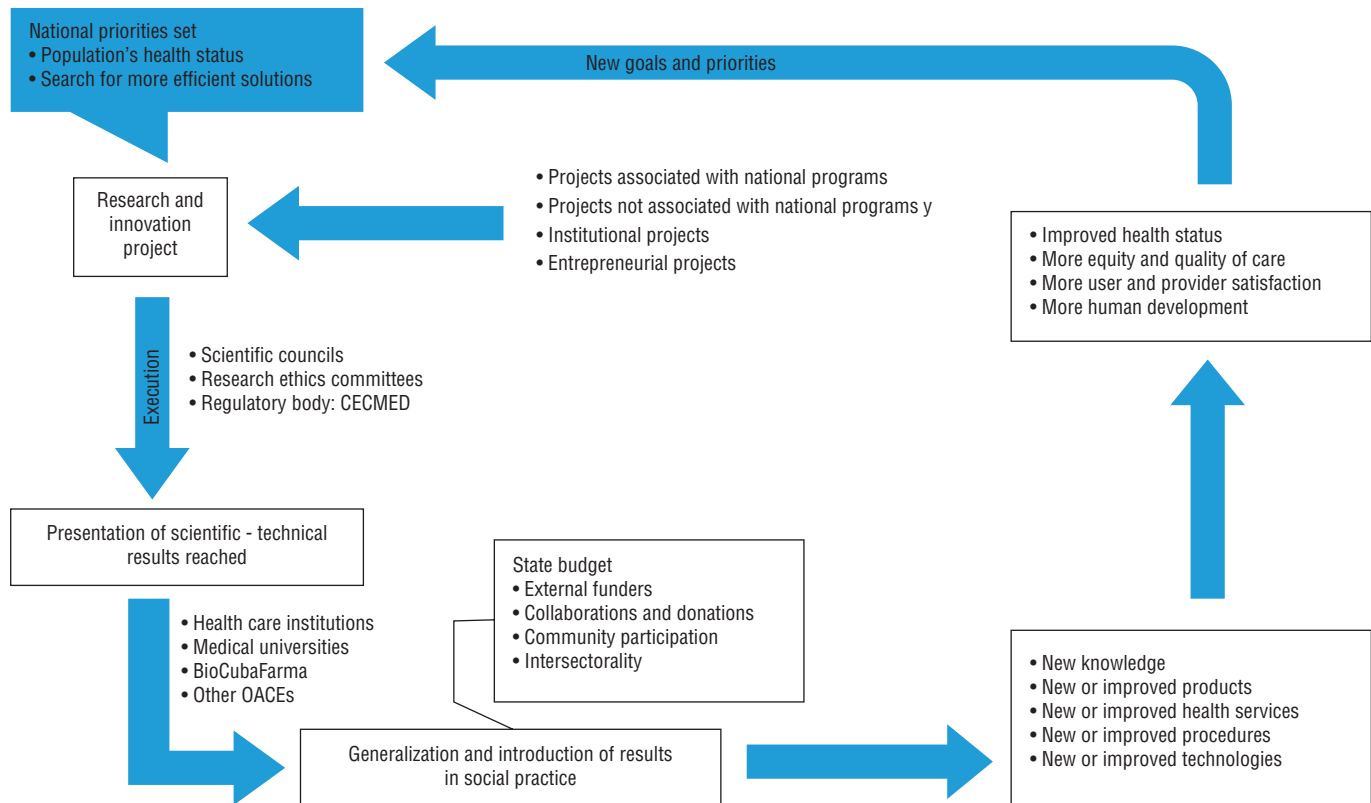
Other challenges include access to funding and proper use of funds, technological obsolescence, facilities maintenance, researcher instability and aging, as well as the dismissive stance toward research and innovation taken by some decision makers (7, 22).

EFFECTS OF RESEARCH ON THE POPULATION’S HEALTH

To illustrate the influence of Cuban SCITS research on health, several research-and-development examples have been selected for their demonstrated contribution to the study and control of priority health problems. These examples combine basic and applied research from biomedical, social and other science perspectives (Table 4).

One example is the generation of health products (medicines, reagents, etc.) and technologies (equipment and

FIGURE 1. Health research process in Cuba, 2016



Note: CECMED: Center for State Control of Medicines and Medical Devices; BioCubaFarma: Biotechnology and Pharmaceutical Industry Group; OACE: Central State Administration Agency.
Source: Created by the authors.

TABLE 3. BioCubaFarma products supplied to the National Health System. Cuba, 2016

Product	Total
Medicines (biotechnology and generic)	499
Reagents	64
Diagnostic tools	135
Equipment	76
Products for oral health use	24
Raw materials for medical care	12
Raw materials for traditional natural and chemical dispensary medicines	53
Total	863

Source: Created by the authors based on references 17 and 18

systems), which are essential to lowering mortality from diseases in Cuba, primarily the four leading causes of death: heart disease (217.7 deaths per 100 000 population), malignant tumors (216.3 per 100 000 population), cerebrovascular diseases (84.2 per 100 000 population) and diabetes mellitus (20.0 per 100 000 population) (13).

In addition, research on dengue and diabetes, and the biopsychosocial study of disability, span health systems and

services, and have led to changes in medical practice, social policies, and specific educational and health care programs for vulnerable groups.

Generating health products and technologies

The first outcome of this type of research was the Ultramicroanalytical System (SUMA), which enables mass screening for several infectious diseases

in the general population and in specific groups, such as pregnant women, blood donors, and human immunodeficiency virus (HIV) carriers (10). By September 2014, more than 48 million SUMA tests had been administered to control transmission of HIV, hepatitis B and C, dengue, Chagas disease and Hansen disease (leprosy). More than 34 million tests had been administered to blood donors to control transmission of HIV and hepatitis B and C (23).

In the framework of the National Maternal-Child Health Program, more than 4 million pregnant women had been tested by 2014. Prenatal detection of congenital defects through measuring alpha fetoprotein in maternal blood has given pregnant women and their partners the option to receive additional tests, genetic counseling, or selective and informed termination of pregnancy, since these techniques can confirm severe congenital fetal defects (24). More than 7 million pregnant women and their partners have been tested to control for vertical transmission of HIV, syphilis and hepatitis B.

TABLE 4. Selected research projects and their effect on population groups' health. Cuba, 2016

Health problem	Research results	Effect on population groups' health
Congenital defects, HIV and hepatitis B infections during pregnancy	Development of the Ultramicroanalytical System (SUMA) for prenatal screening, available in hospitals, blood banks and research institutes	<ul style="list-style-type: none"> • 4 098 860 alpha-fetoprotein tests; defects detected in 6.4%; infant mortality reduced to 2.1 per 100 000 live births; coverage: >98% of pregnant women in country • Hepatitis B: 1 824 520 tests; 1.4% positive • HIV 1+2: 5 818 895 tests; 0.2% positive; in 2015 WHO declared elimination of vertical transmission of HIV and syphilis in Cuba
Congenital diseases	Development of SUMA technology for neonatal screening, available in hospitals, blood banks and research institutes	Congenital hypothyroidism (801 cases detected in 3 350 373 samples analyzed), phenylketonuria (20 cases in 1 055 575 samples), suprarenal hyperplasia (45 in 780 771), biotinidase deficiency (5 in 759 935) and galactosemia (7 in 723 182)
Transmission of HIV and hepatitis B and C through transfusion; mass screening and epidemiologic control	Development of SUMA technology for certifying blood donations and epidemiologic control, available in hospitals, blood banks, and research institutes	<p>Blood donors:</p> <ul style="list-style-type: none"> • HIV 1+2: 12 798 394 tests; 0.7% positive • Hepatitis B: 12 074 614 tests; 0.9% positive • Hepatitis C: 10 017 461 tests; 0.9% positive <p>Epidemiologic control:</p> <ul style="list-style-type: none"> • HIV 1+2: 35 514 618 tests; 0.6% positive • Hepatitis B: 9 365 416; 1.2% positive • Hepatitis C: 2 226 778 tests; 5.3% positive • Dengue (IgM): 980 104 tests; 32.7% positive • Chagas disease: 14 213 tests; 4.8% positive • Leprosy: 31 725 tests; 10.6% positive
Vaccine-preventable communicable diseases	Heberpentax® combined pentavalent vaccine against diphtheria, tetanus, whooping cough, hepatitis B and <i>Haemophilus influenzae</i> type b ^a Meningococcal BC vaccine ^a	Registered in 2010; simplified the National Immunization Program by reducing the number of vaccinations from 11 to 6. Vaccination coverage >98.7%
High mortality from acute myocardial infarction	Heberkinasa®, human recombinant streptokinase, thrombolytic biopharmaceutical	Mass vaccination campaign in 1989. Included in the National Immunization Program since 1991. Incidence reduced from 14 per 100 000 population in the 1980s to <0.2 per 100 000 population in 2006
High incidence of ischemic heart disease	Policosanol (PPG®) ^a hypolipemizing pharmaceutical, platelet aggregation inhibitor of natural origin	Since its introduction in 1991, hospital mortality from acute myocardial infarction reduced 50%–70%; the medication is available in primary health care centers with progressive care units
Neutropenia in patients with hematological cancer, HIV/AIDS, or secondary treatment with chemotherapy or radiation therapy	ior®-LeukoCIM, granulocyte colony-stimulating biopharmaceutical	Treatment of hypercholesterolemia (coronary risk factor); incorporated into the CBM since 1991, available in pharmacies
Mortality from non-small cell lung cancer	CIMAvax-EGF®, therapeutic vaccine	Incorporated into the CBM and available in hospitals since 2004; effective in recovery of absolute neutrophil count in patients with hematological cancer (adults and children) or HIV/AIDS; shorter hospital stay; lower risk of associated infections; improved quality of life
Diabetic foot ulcers and amputations	Heberprot-P®, recombinant epidermal growth factor applied by intra-lesion injection ^a	Active immunotherapy; incorporated into CBM; increased survival and quality of life
Diabetes and self-care	National Diabetic Patient Education Program and its implementation	More than 20 000 diabetic patients treated in more than 85 health institutions (by 2014); establishment of the Comprehensive Care Program for Patients with Diabetic Foot Ulcers (includes use of the product) that coordinates actions at the primary and secondary care levels; incorporated into the CBM since 2007; amputations index reduced by 81.2% (12 000 amputations prevented)
Dengue and hemorrhagic dengue	Identification of early warning signs of the disease	Lower medicine dosages in non-insulin-dependent patients; HbA levels reduced from 12% to 7.6%; frequency of excess body weight reduced from 77% to 20% of cases; and average annual hospitalizations due to metabolic decompensation in diabetes type 1 reduced from 2–3 per person to <1
Health and socioeconomic status of persons with disabilities	Description of the magnitude and scope of the problem	Incorporated into the norms for therapeutic management in the guidelines of Cuba, WHO and other countries of the Region; classification of cases: 96% sensitivity and 100% specificity
		Study of 366 864 persons with disabilities (prevalence: 3.26%); community programs developed in genetics, rehabilitation and social work; technical, monetary and nutritional aid implemented; a law protecting mothers with affected children was passed and went into effect: since 2016, 7 462 mothers of individuals with severe disabilities have been protected

^a Cuban inventions awarded with Gold Medals by the World Intellectual Property Organization (WIPO). In the pentavalent vaccine only the *Haemophilus influenzae* type b component (synthetic antigen) received the award (10).

Note: CBM: essential medicines list; HbA: Glycosylated hemoglobin; WHO: World Health Organization; HIV: Human Immunodeficiency Virus

Source: Created by the authors based on references 10, 17, 18, 23–38.

As a result, Cuba was designated the first country in the world to eliminate mother-to-child transmission of HIV and congenital syphilis (25). Today, this program covers the care of more than 95% of pregnant women in the country (24).

Research has also spawned domestic production of 8 of the 11 vaccines that make up the National Immunization Program, which has achieved >98% coverage. Diseases such as tetanus, meningococcal meningitis, *Haemophilus influenzae* type b

infection and typhoid fever have ceased to be a health problem in Cuba, while morbidity and mortality from hepatitis B have been reduced by more than 98% (26).

In addition to preventive vaccines, biotechnology provides other products to

the SNS, such as biopharmaceuticals to treat non-communicable diseases (cardiovascular, cancer, diabetes, and others). Another example is the group of technologies developed for screening, detection and early treatment of cervical cancer, supplied to the SNS since 2010; in 2012–2014, 71.8% of women aged 25–64 years were tested, an advance compared with 2009. However, this percentage remained below the 80% coverage recommended by WHO to determine if these interventions have influenced the reduction in mortality from cervical cancer (39).

BioCubaFarma's products and technologies are part of the Essential Medicines List (17) and other MINSAP applications, thus significantly reducing imports.

Educating people with diabetes

Research and interventions by the National Endocrinology Institute on the knowledge, attitudes and practices of people with diabetes have been an essential pillar of the National Diabetes Care and Patient Education Program since it was implemented in 1981 (31). The results have helped prevent complications and improve quality of life for diabetic patients, who have not needed to resort to new types of insulin or other technologies. Although Heberprot-P® has been introduced as an effective treatment for diabetic foot ulcers (30), research also showed that patients obtain maximum benefit from the product only with strict adherence to the program's therapeutic and hygienic norms.

Studies found that patients' increased knowledge and skills related to daily care (independent of age, education level, and type and duration of diabetes) were associated with a marked decline in average glycosylated hemoglobin (HbA_{1c}) levels and reductions in dosages of medicines, frequency of excess body weight, and average number of hospitalizations due to decompensation (31, 32).

The presentation and development of long-term complications in patients with recent onset of type-1 diabetes were also studied. Frequency of diabetic retinopathy was found to be significantly lower in the group monitored with an interactive methodology based on constructive dialogue between the person providing information and the one receiving it,

compared with patients who received only individual counseling through traditional medical checkups. In the former group, concerns are listened to, skills are developed to manage different therapeutic demands, and efforts are made to develop motivation and self-confidence for confronting problems. Similar results were obtained when evaluating the evolution of nephropathy and peripheral neuropathy (31).

All this does not minimize the magnitude of diabetes as a health problem. Working in the community with patients and the general population to prevent diabetes must, therefore, continue, emphasizing full compliance with medical, health and hygienic treatment (32). Promoting the importance of personal responsibility in health continues to be fundamental (40).

Dengue research

These studies reached their height in 1981 when Cuba suffered a lethal hemorrhagic dengue epidemic (41). Initial efforts focused on the disease's epidemiology, on describing the clinical evolution of children who died from severe dengue, and on its warning signs, defined as "a group of signs and symptoms indicating the imminent onset of shock from dengue" (36). These studies received recognition from the Pan American Health Organization (PAHO) and WHO as the guidelines for early detection of patients evolving toward severe dengue, who require a different type of treatment (33–35). The prospective DENCO study (36), which included more than 1 700 confirmed cases, showed that the classification based on warning signs and initially used in Cuba had 96% sensitivity and 100% specificity. As a result, it was incorporated into WHO policy documents and into guidelines in Cuba and other countries in the Region for comprehensive management of dengue patients.

The most important of these studies, led by the Pedro Kourí Tropical Medicine Institute, include establishment of the comprehensive hypothesis about hemorrhagic dengue (41), virologic studies to describe the viruses causing the epidemics and outbreaks of dengue in Cuba, and virulence markers and their association with severe dengue. These studies have also benefited other countries in the Region.

Entomological studies and operations research on controlling the *Aedes aegypti* mosquito have identified and described the vector's main breeding sites and resistance mechanisms. BioCubaFarma and other centers are also working to obtain a candidate vaccine against the disease.

Research on socioeconomic determinants, and social and intersectoral participation, are also relevant, as well as studies of public knowledge, attitudes and practices. Despite measures taken by MINSAP and government support, at the end of 2016 some municipalities still had infestation indices⁸ above the maximum level allowed for control of epidemics established in the National *Aedes aegypti* Eradication Program (0.05), which confirms the importance of socioeconomic determinants for controlling dengue. These investigations currently include the study of other arboviruses caused by the same vector (42).

Biopsychosocial study of people with disabilities

Persons with disabilities constitute one of the most vulnerable sectors in any society; their study and care are a challenge in any country. In Cuba, the first comprehensive study of people with disabilities was designed and conducted in 2001–2003 (37).

The study included 366 864 individuals with a disability (3.26% prevalence in the surveyed population). The highest rates were found in the provinces of Guantánamo (4.13%) and Santiago de Cuba (3.79%).

The survey detected 140 489 people (38.29%) with an intellectual disability, for a prevalence of 1.25%. Of those, 92 506 (25.2%) presented a physical-motor disability, for a prevalence of 0.82%; 46 455 (12.7%) had a visual disability (0.41% prevalence); 36 869 (10.1%) mental disability (0.33% prevalence); 23 620 (6.4%) auditory disorders (0.21% prevalence); 25 094 (6.8%) presented mixed disabilities (0.22% prevalence); and 1 831 (0.5%) were diagnosed with chronic kidney failure (0.02% prevalence) (37).

The following disability programs are highlighted in the results of the study:

- Community-based programs: genetics, rehabilitation and social work;

⁸ Indicates the degree of infestation by the vector in the area surveyed, expressed as the percentage of dwellings and other sites that tested positive with respect to the total number inspected (42).

TABLE 5. Lessons learned

Health research in Cuba and its application are a reality thanks to:

- The political will of the State, which has provided funding, coordination and generation of synergies between health services, research centers, enterprises in different sectors and the disciplines, enabling a developing country to conduct research and introduce cutting-edge technologies to raise the health standards of its population.
- Establishment of the Science and Technological Innovation System in Health (SCITS), since the State is committed to defining research and development priorities and to contributing contributes most of the resources.
- SCITS' dynamism in adapting its priorities, organization and functioning to changing social and health needs.
- The systematic care and formation of human capital, dialogue with decision-makers, methodological rigor, and researchers' ethics and social commitment needed in order for SCITS to meet its objectives.

- Establishment of 23 lines of research on factors associated with disability;
- Legal recognition of the condition of "caregiver mother," who receives a full salary for caring for her disabled child at home;
- Technical and economic assistance, and free meals, provided to persons with disability.

In 2007–2010, the research was replicated in Venezuela, Ecuador, Nicaragua, Bolivia, and St. Vincent and the Grenadines, at the request of their governments (43).

Final considerations

The research reviewed on each of the selected topics are examples of how solutions emerge from overlaps between different disciplines in the biomedical sciences, and that "progress is made not only by those who are most knowledgeable but by those who best combine their knowledge" (21).

The results obtained are the product of a long and arduous process, involving political will, developing human capital, building a national industry, creating the material and financial operating conditions, and the need to resolve contradictions between epistemological positions and knowledge, or between managers and researchers (Table 5).

CONCLUSIONS

SCITS in Cuba is sustained by a national policy that promotes science at all levels of health care and that has solved priority health problems. It faces challenges common to other countries in the region, such as access to funding, technological obsolescence and preservation of human capital, derived from constraints imposed on the economy and changes in the socioeconomic context.

The research presented offers important contributions that have been

introduced into health practice in the form of policies, programs, products, technologies, and high quality social and health care services. These advances have provided coverage for the population in need and have had a positive effect on their health status. Even so, given their magnitude and complexity, these and other problems will continue to be objects of scientific study in the health sciences *ad infinitum*.

Conflicts of interest. None declared. Dr. V. Gustavo Sierra González works for BioCubaFarma.

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RESUMEN

Ciencia e innovación tecnológica en la salud en Cuba: resultados en problemas seleccionados

En Cuba, la investigación para la salud se basa en las prioridades de la política científica nacional, derivadas del estado de salud de la población. El objetivo de este artículo es describir las características del Sistema de Ciencia e Innovación Tecnológica en el sector y cómo los resultados de sus investigaciones benefician la salud de los grupos poblacionales. Para ello se seleccionaron investigaciones relacionadas con la generación de productos y tecnologías, la diabetes, el dengue y la discapacidad. Este sistema sigue los preceptos metodológicos del Ministerio de Ciencia, Tecnología y Medio Ambiente y cuenta con 37 entidades de investigación. Se organiza en programas y proyectos que favorecen la investigación básica y aplicada, con un enfoque multidisciplinario e intersectorial; estos son financiados mayormente por el Estado y organizados en ciclos cerrados o completos, es decir, una misma entidad se encarga de todo el proceso, desde la investigación hasta la comercialización, incluidos los estudios de mercados y la vigilancia poscomercialización. Las investigaciones seleccionadas evidencian la armonía entre la investigación, la generalización de los resultados y su efecto en mejorar la salud y el acceso universal de la población. Se lograron resultados en métodos de diagnóstico, vacunas preventivas y terapéuticas, signos de alarma para el pronóstico y tratamiento del dengue, prevención de malformaciones congénitas, y políticas y programas que han beneficiado a las personas con discapacidad y sus familiares. La voluntad del Estado para desarrollar y financiar la investigación científica, la acción intersectorial, la definición de las prioridades de investigación, y la preparación y atención sistemática del capital humano han sido factores determinantes para el cumplimiento de los objetivos del sistema.

Palabras clave

Política nacional de ciencia, tecnología e innovación; gestión de ciencia, tecnología e innovación en salud; investigación biomédica; planes y programas de salud; proyectos de investigación; Cuba.

Ciência e inovação tecnológica em saúde em Cuba: resultados em problemas selecionados

RESUMO

Em Cuba, a pesquisa em saúde baseia-se nas prioridades da política científica nacional, derivadas do estado de saúde da população. O objetivo deste artigo é descrever as características do Sistema de Ciência e Inovação Tecnológica e como os resultados de suas pesquisas beneficiam a saúde dos grupos populacionais. Para este fim, foram selecionadas pesquisas relacionadas à geração de produtos e tecnologias, diabetes, dengue e deficiência. Este sistema segue a metodologia do Ministério da Ciência, Tecnologia e Meio Ambiente e possui 37 entidades de pesquisa. Está organizado em programas e projetos que favorecem pesquisas básicas e aplicadas, com abordagem multidisciplinar e intersetorial; estes são financiados principalmente pelo Estado e organizados em ciclos fechados ou completos, ou seja, a mesma entidade é responsável por todo o processo, desde pesquisa até marketing, incluindo estudos de mercado e vigilância pós-comercialização. As pesquisas selecionadas mostram a harmonia entre a pesquisa, a generalização dos resultados e seus efeitos na melhoria da saúde e no acesso universal à saúde na população. Resultados positivos foram obtidos em métodos de diagnóstico, vacinas preventivas e terapêuticas, sinais de alerta para o prognóstico e tratamento da dengue, prevenção de malformações congênitas e políticas e programas que beneficiaram pessoas com deficiência e suas famílias. A vontade do Estado de desenvolver e financiar pesquisas científicas, ações intersetoriais, a definição de prioridades de pesquisa e o treinamento e atenção sistemática do capital humano têm sido fatores determinantes para o cumprimento dos objetivos do sistema.

Palavras-chave

Política nacional de ciência, tecnologia e inovação; gestão de ciência, tecnologia e inovação em saúde; pesquisa biomédica; planos e programas de saúde; projetos de pesquisa; Cuba.
