# AIDS IN COSTA RICA: ESTIMATES FOR 1990-1994 BY THE QUADRATIC AND OTHER SIMPLE EQUATIONS

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*ABSTRACT*

*The 1990-1994 projections of the AIDS epidemic in Costa Rica were calculated using five equations: linear, exponential, logarithmic, power and quadratic. The quadratic and power equations gave he best fit. The quadratic model yielded projections for AIDS from all risks which were in agreement with the observed trend of the epidemic. The projections for the current quinquenium suggest that the epidemic will evolve predominantly among homosexual and bisexual men, without an unusual significant increase in the heterosexual population in the near future. The application of heuristic methods for forecasting the AIDS epidemic in small countries like Costa Rica is risky, due to inadequate notification and to the few cases recorded in the early years of the epidemic. However, the exercise is justified because it enhances awareness among health authorities and policy makers; is useful for estimation of medical and psychosocial needs; and helps assessing the potential socioeconomic impact of AIDS.*

*RESUMEN*

*La proyección de la epidemia del síndrome de inmunodeficiencia adquirida (SIDA) en Costa Rica fue calculada para el quinquenio 1990-1994, mediante cinco ecuaciones: lineal, exponencial, logarítmica, de potencia y cuadrática. Se obtuvieron muy buenos ajustes con las curvas cuadrática y de potencia. La curva cuadrática fue el mejor modelo para el SIDA por todos los riesgos, y las proyecciones fueron compatibles con la tendencia observada de la epidemia. El SIDA seguirá extendiéndose principalmente entre hombres homosexuales y bisexuales, sin que exista evidencia fuerte de un incremento significativo en la población heterosexual en el futuro cercano. El empleo de métodos heurísticos para vaticinar epidemias de SIDA puede ser riesgoso en países pequeños, especialmente cuando sólo han aparecido pocos casos al inicio de la epidemia. No obstante, el ejercicio sirve para despertar inquietudes entre las autoridades de salud y los planificadores, así como para determinar las necesidades médicas y psicosociales, y evaluar el posible impacto económico y social del problema.*

/ KEY WORDS: / Acquired immunodeficiency syndrome / AIDS / AIDS control and prevention /
/ PALABRAS CLAVES: / Síndrome de inmunodeficiencia adquirida / SIDA / Control y prevención del SIDA /

## *Introduction*

Acquired immunodeficiency syndrome (AIDS) in Costa Rica was clinically recognized in 1984 in four hemophiliacs. About one half of the hemophiliacs in the country, estimated at 120, had developed antibodies to the human immunodeficiency virus (HIV) in the early 1980's (Cordero *et al.*, 1988). By the end of 1989, 22 had progressed onto AIDS, accounting for 14.6 per cent of the cases from all risk factors *(Table I, Figure 1)*. From 1985 onwards, all Factor VIII imported by Costa Rica was required to be prepared from blood free of HIV antibody, and preheated by an accepted method. Hemophiliacs do not appear to contribute to the spread of HIV within their group or to other populations because they are nonpromiscuous. Hemophiliacs also benefit from close medical supervision and counselling.

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In contrast, a significantly larger and expanding epidemic of AIDS is currently underway among homosexual and bisexual men (Mata and Herrera, 1988). The first case in a homosexual was diagnosed in 1985: six cases were recorded in 1986, 18 in 1987, 39 in 1988, and 43 during 1989. This increasing number reflects a rising rate of HIV infection among homosexual and bisexual men. In fact, an ongoing cohort study of homosexual men revealed a steady increase of HIV-antibody positives from 5 per cent by mid 1985 to 18 per cent in the early 1988 (Mata *et al.*, 1988). Bisexual men had an infection rate about one half that seen in homosexual men (Mata *et al.*, 1989).

Few cases of AIDS have been detected in persons other than those with homosexual or hemophiliac risk. ELISA screening of virtually the entire blood supply had been attained in Costa Rica in October of 1988 (Mata and Herrera, 1988), and therefore, transmission of HIV through blood transfusion has been minimal after that date. All but two of nine transfusion-related HIV infections (not yet progressing onto AIDS) presumably occurred before the implementation of the screening. Most blood donors linked to transfusion-mediated HIV infection were homosexual men. Blood donors in Costa Rica are altruistic and about 30 per cent of them are women. Additional control of transfusion mediated infection was attempted by 1986 legislation banning persons with risky behavior from blood donation (Ugalde and Mata, 1988).

Intravenous drug users (IVDU) are rare in Costa Rica, and only a few of them are known to have HIV antibody. However, IVDU are very secluded, and there is no data on how many of those with only that risk have been tested for HIV antibody.

There are about three dozen known HIV-positive women, most of whom have one or two of the following risks: a) sexual contact with men from countries with high HIV infection rates, b) bisexual sex patner, and c) blood transfusion or recipient of blood products. Most are housewives and only three are sex workers.

The objectives of this study are: a) to estimate the number of AIDS cases for the quinquenium 1990-1994, b) to compare the fitted values with the reported cases since the beginning of the epidemic, and c) to provide a base for estimation of the mortality, morbidity and other impact of the epidemic.

TABLE I

AIDS BY RISK GROUP AND YEAR OF DIAGNOSIS, COSTA RICA

| *Group or Risk* | *84* | *85* | *86* | *87* | *88* | *89* | *All* |
|---|---|---|---|---|---|---|---|
| Homosexual men | | 1 | 6 | 14 | 35 | 36 | 92 |
| Bisexual men | | | | 4 | 4 | 7 | 15 |
| Total homosexual | | 1 | 6 | 18 | 39 | 43 | 107 |
| Hemophiliacs | 4 | 3 | 4 | 4 | 6 | 1 | 22 |
| Transfusion | | | 1 | | | 2 | 3 |
| IV drug use | | | | | 1 | 1 | 2 |
| Heterosexual, women | | 1 | | | 2 | 3 | 6 |
| Heterosexual, men | | | | | 1 | 2 | 3 |
| Perinatal | | | | | 1 | 3 | 4 |
| Unknown | | | | 1 | 2 | 1 | 4 |
| Total | 4 | 5 | 11 | 23 | 52 | 56 | 151 |

Source of data: Epidemiologic Surveillance, Ministry of Health, Costa Rica.

TABLE II

EQUATIONS USED TO FIT THE COSTA RICAN DATA

| | |
|---|---|
| linear: | $y = a + b(x)$ |
| exponential: | $y = a\ e^{bx}$ |
| logarithmic: | $y = a + b\ \ln(x)$ |
| power: | $y = a\ x^b$ |
| quadratic: | $y = a + b(x) + c\ x^2$ |

a = intercept
b = slope
c = parameter reflecting deceleration
ln = natural logarithm

## Methodology

*Assumptions.* For the period 1990-1994, the following was assumed: a) an effective drug against HIV infection and/or AIDS will not be available in Costa Rica, b) a vaccine against HIV infection will not be available, c) no detectable change will occur in host susceptibility or in virulence of the agent, and d) no significant change will be observed in sexual behavior and life-style of population groups known or suspected to have the highest HIV infection risk (Mata and Valadez, 1988a).

*Data.* All diagnosed AIDS cases in Costa Rica were included in the analysis, from 1984 —the year in which the first case was accurately diagnosed — through 31 December 1989 *(Table I)*. Cases included foreigners who developed AIDS in Costa Rica, nationals who had returned and eventually got the syndrome, and other persons with AIDS — nationals and foreigners — who had not been abroad since 1978. Due to the small size of the population of Costa Rica (2.9 million in 1989) and to the fact that the epidemic is just running its sixth year (all AIDS) or fifth year (homosexual AIDS) of evolution, only six or five yearly data points, respectively, were available for calculation. Furthermore, data for 1984, and 1985 consisted of only a handful of cases *(Table I)*.

*Models.* Five mathematical equations were used: linear, exponential, logarithmic, power and quadratic *(Table II)*. These curves can be used to fit data points of a variety of growth phenomena. Two sets of data were fitted with these equations as follows: a) AIDS from all risks, from 1 January 1984 through 31 December 1989; and b) AIDS only in homosexual and bisexual men, from 1 January 1985 through 31 December 1990 (see *Table I*). Fitting was made by computer.

## Results

The calculated values of the parameters of the five equations, the calculated estimates for 1984-1989, and the projections for the quinquenium 1990-1994 for all the AIDS cases are in *Table III*. The graphic expression of the projected epidemic is in *Figure 2*. The best were obtained with the quadratic and exponential equa-

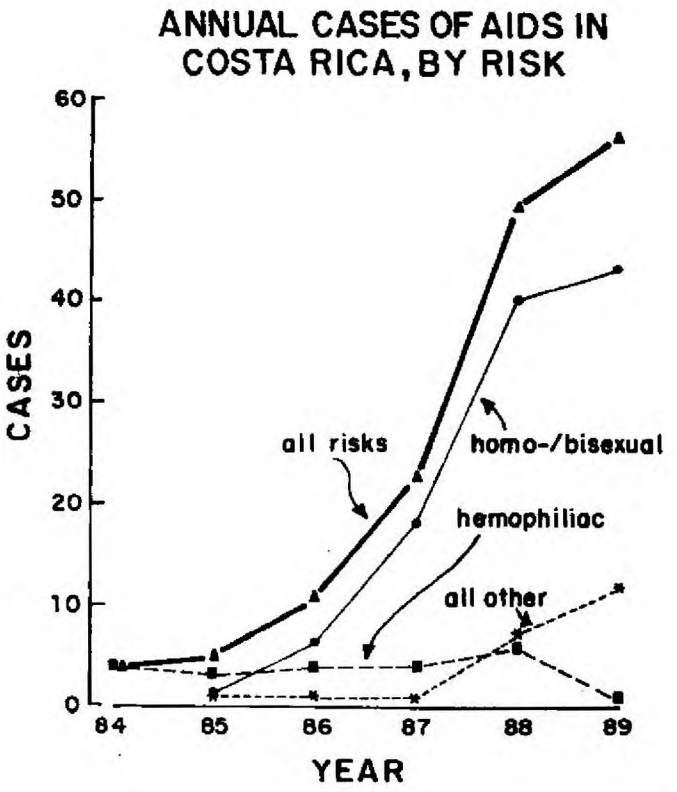


Figure 1. AIDS in Costa Rica by risk. Most cases are in men with homosexual and bisexual behavior. Note that in 1989 there seem to be fewer cases than one would expect. Source of data: Epidemiologic Surveillance, Division of Epidemiology, Ministry of Health.

tions, yielding $R^2$ values of 0.94 and 0.96, respectively. However, only the quadratic and power equations gave projected values in relative agreement with the actual trend of observed cases *(Figure 2)*. The power curve provided a good fi, although not as good as that obtained with the quadratic curve.

The calculated values of the parameters and the projections of AIDS in only homosexual men are in *Table IV*. With these data, the best $R^2$ values were obtained with the power, quadratic, and linear equations. In this case, the projections which agreed better with the observed trend were those obtained with the power curve *(Figure III)*. The other equations did not give as good fit, or else resulted in projections which were either too small or too large to be acceptable.

The accumulated projected AIDS cases in Costa Rica, obtained with the quadratic and power equations, are presented in *Table IV* and *Figure 4*. As expected, AIDS cases linked to homosexual behavior are slightly less than those of AIDS attributable to all risks. Expectedly, the corresponding curves run parallel to each other.

*Discussion*

Global and national forecasting of the AIDS epidemic has become an important activity of scholars at the World Health Organization and many institutions throughout the world (Public Health Service, 1986; May and Anderson, 1987; Anderson *et al.*, 1987; Valdespino *et al.*, 1988; Mata and Valadez, 1988b; Chin, 1988; Chin and Mann, 1989; Center for Disease Control, 1990). The effort has met with skepticism and rebuttal (Langmuir, 1988), but it has been worthwhile. Estimates for Europe, North America and some Latin American countries actually hold through or even fall short of reality (Chin and Mann, 1989; Valdespino *et al.*, 1989; Mata and Valadez, 1988b).

The first projections of the AIDS epidemic in Costa Rica were obtained in June 1987 using the power curve (Mata and Valadez, 1988a). This equation yielded sensible estimates in 1988 calculations (Mata and Valadez, 1988b). However, in the present occasion, the power curve gave a good estimate only for AIDS in homosexual

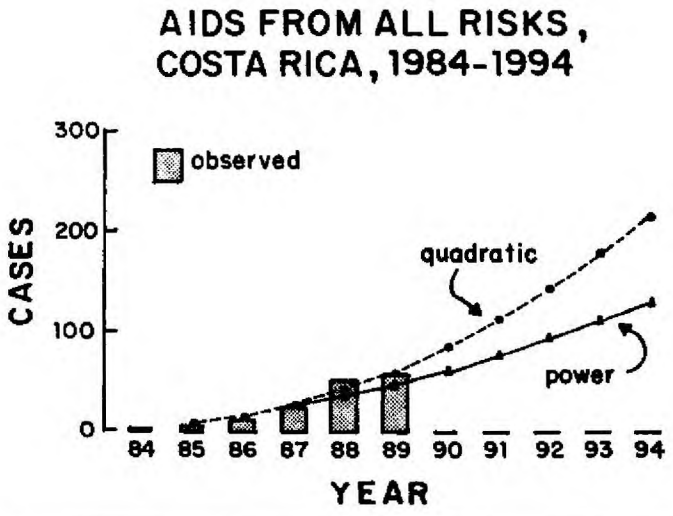


Figure 2. Observed (1984-1989) and estimated (1990-1994) AIDS cases in Costa Rica, from all risks. Estimation was by the quadratic and power curves. These models gave good fits for total AIDS.

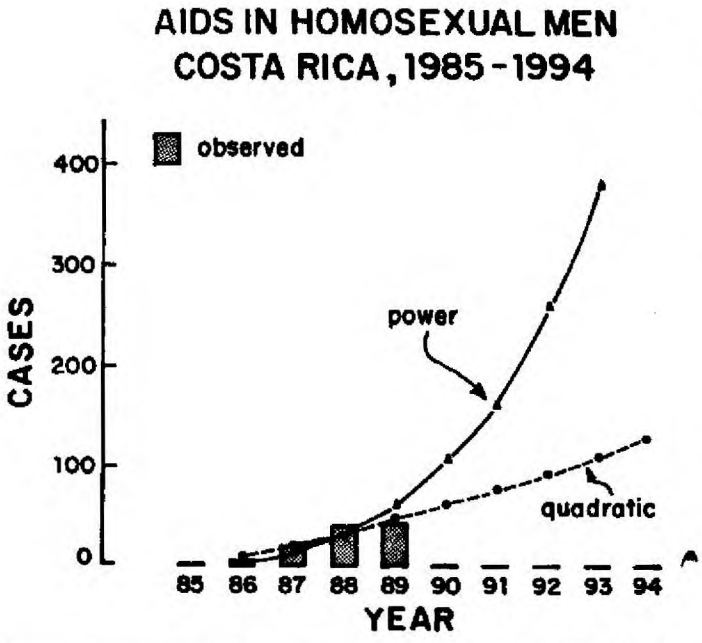


Figure 3. Observed (1985-1989) and estimated (1990-1994) AIDS cases, for homosexual risk only. Estimation was by the quadratic and power curves. The quadratic equation fitted the data best.

TABLE III

VALUES OF THE EQUATIONS AND ESTIMATED AIDS CASES FROM ALL RISKS, COSTA RICA, 1984-1994

| *Year* | *Linear* | *Exponential* | *Logarithmic* | *Power* | *Quadratic* |
|---|---|---|---|---|---|
| 1984 | —4.3 | 3.5 | —7.7 | 2.6 | 2.0 |
| 1985 | 7.5 | 6.4 | 13.1 | 8.1 | 6.2 |
| 1986 | 19.3 | 11.6 | 25.2 | 15.7 | 14.2 |
| 1987 | 31.1 | 21.1 | 33.9 | 25.1 | 26.0 |
| 1988 | 42.9 | 38.4 | 40.6 | 36.0 | 41.6 |
| 1989 | 54.7 | 70.0 | 46.0 | 48.5 | 61.0 |
| 1990 | 66.5 | 127.3 | 50.7 | 62.3 | 84.3 |
| 1991 | 78.3 | 231.7 | 54.7 | 77.4 | 111.4 |
| 1992 | 90.1 | 421.7 | 58.2 | 93.7 | 142.3 |
| 1993 | 101.9 | 767.6 | 61.4 | 111.2 | 177.0 |
| 1994 | 113.7 | 1,396.9 | 64.2 | 129.9 | 215.6 |
| Values of equations: | | | | | |
| a | —16.1333 | 1.9254 | —7.7407 | 2.6335 | 1.7 |
| b | 11.8 | 0.5988 | 30.0101 | 1.6257 | —1.575 |
| c | | | | | 1.9107 |
| $R^2$ | 0.8923 | 0.9650 | 0.7241 | 0.8923 | 0.9422 |

men *(Table IV)*, while the quadratic curve provided a much better fit of all AIDS data collected until the end of 1989.

The projections obtained for Costa Rica may have appeared overestimated to some, but such claims were made by those who also denied the magnitude and significance of the epidemic. What matters is that the projections obtained in 1987 and 1988 actually exceeded observed numbers in those two years (Mata and Valadez, 1988). The use of heuristic methods to estimate the trend of the epidemic at frequent intervals has value, even though the epidemic in Costa Rica is barely in its fifth or sixth year of evolution and the early data points were small. Eventually, the models employed in this analysis, or better ones brought to attention in the future, might forecast numbers of AIDS cases with greater accuracy in Costa Rica and other small countries. At the moment, the quadratic and power equations appear to be good choices, not only because they give very high $R^2$ values, but because the estimates for total and homosexual AIDS are in agreement with the observed trend of the epidemic.

Deficient notification of cases, a phenomenon which seemed to have increased during 1989, might have limited the power of modelling. For instance, only 56 AIDS cases were reported in 1989, as compared with 52 in the preceding year *(Table I, Figure 1)*. Such unexpected finding was likely the result of under reporting due to difficulty in recognizing and diagnosing cases, to migration of persons with HIV infection or AIDS to other countries, and to seclusion of persons with AIDS out of fear of mistreatment and discrimination in the hospitals (Mata, 1989). Also, a greater number of persons treated with zidovudine in Costa Rica during 1989, probably delayed reporting of cases to the Ministry of Health, either because patients improved or because physicians waited for the outcome of treatment before reporting. Under reporting is universal, especially in less developed countries with faulty health systems (Chin and Mann, 1989). Some of these factors have been documented, for instance, about 10 per cent of the HIV — antibody positive men in a cohort of homosexual and bisexual men (Mata *et al.*, 1988) have migrated to industrial nations, especially the United States, in search of better medical care and less stigmatization (Mata *et al.*, 1989a).

Accumulation of expected cases of AIDS helps to anticipate needs for medical and psychosocial support, particularly because persons with HIV infection or AIDS run a prolonged course which is invariably fatal. The present estimates indicate that AIDS is a leading public health problem of Costa Rica. Its

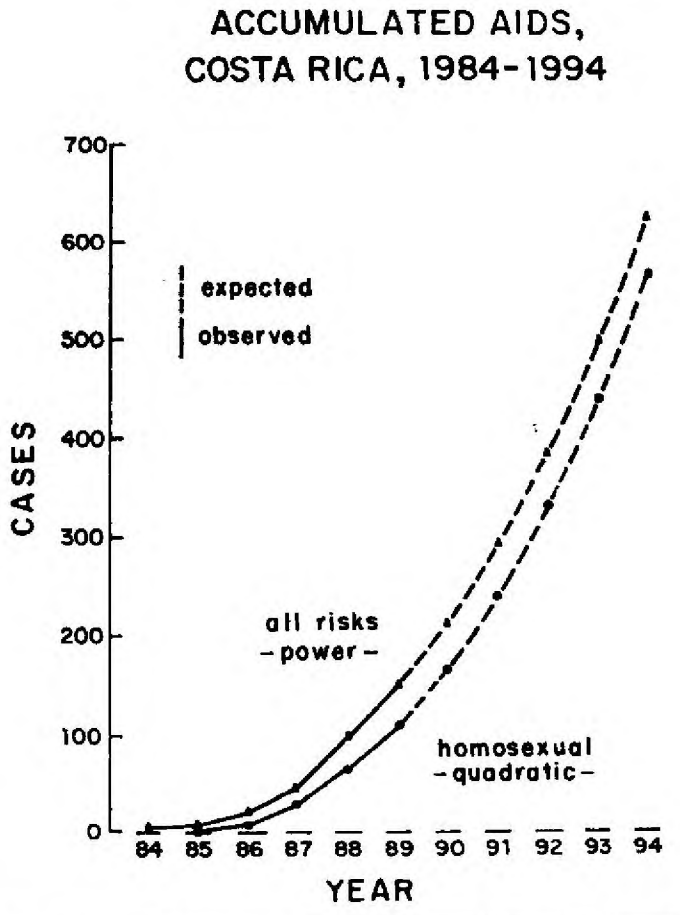


Figure 4. Accumulated projected AIDS in Costa Rica, 1984-1994, by the quadratic and power equations, for AIDS of homosexual and all risks combined.

contribution to the morbidity of adults will be more evident in the next two years, when it probably will exceed those of other causes, including many infectious and parasitic diseases. In fact, the 1989 AIDS mortality - 0.02 per 1,000 population — was already one half that due to diarrhea — 0.04 per 1,000. The social impact will be increasingly great if measured in terms of years of potential life lost, because AIDS affects primarily adults at the plenitude of life. The AIDS epidemic will increase the demand for medical resources as it evolves. It may also congest health care facilities, psychosocial clinics and other support services during this decade, unless alternatives are found for instance ambulatory care or support in hospices and refuges (Mata, 1989). The evolving AIDS epidemic will also demand considerably larger budgets (Mata and Herrera, 1988) and more complex and expensive legal procedures (Ugalde and Mata, 1988).

HIV/AIDS probably will rise among the heterosexual population, in a similar fashion as that noted in the Dominican Republic, Honduras and Brazil. This is to be expected owing to the relatively high frequency of bisexuality among homosexual men, estimated at 30 per cent in a local study (Mata *et al.*, 1989b). So far, only four per cent of the total AIDS cases in Costa Rica have been among women, mainly housewives, and all but one acquired it from their spouses. The association of AIDS with homosexual behavior by the general populations has established equivocal belief that it will not strike among heterosexuals. It has also determined that heterosexuals have a lower rate of acquisition of "safer sex" practice as well as a very low rate seeking the AIDS test.

TABLE IV

VALUES OF THE EQUATIONS AND ESTIMATED AIDS CASES FROM HOMOSEXUAL RISK, COSTA RICA, 1985-1994

| *Year* | *Linear* | *Exponential* | *Logarithmic* | *Power* | *Quadratic* |
|---|---|---|---|---|---|
| 1985 | —2.0 | 1.7 | —4.5 | 1.2 | —1.0 |
| 1986 | 9.7 | 4.4 | 12.4 | 5.2 | 9.2 |
| 1987 | 21.4 | 11.3 | 24.3 | 14.5 | 20.4 |
| 1988 | 33.1 | 28.8 | 33.6 | 32.0 | 32.6 |
| 1989 | 44.8 | 73.7 | 41.2 | 61.3 | 45.8 |
| 1990 | 56.5 | 188.6 | 47.6 | 106.2 | 60.0 |
| 1991 | 68.2 | 482.5 | 53.1 | 170.8 | 75.2 |
| 1992 | 79.9 | 1,234.6 | 58.0 | 259.8 | 91.4 |
| 1993 | 91.6 | 3,158.7 | 62.6 | 378.1 | 108.6 |
| 1994 | 103.3 | 8,081.5 | 66.3 | 530.8 | 126.8 |
| Values of equations: | | | | | |
| a | —25.4 | 0.2628 | —33.2482 | 0.1039 | —18.4 |
| b | 11.7 | 0.9394 | 41.5307 | 3.5609 | 7.7 |
| c | | | | | 0.5 |
| $R^2$ | 0.9498 | 0.8989 | 0.9007 | 0.9720 | 0.9523 |

TABLE V

ACCUMULATED PROJECTED AIDS CASES, QUADRATIC AND POWER EQUATIONS, BY RISK, COSTA RICA, 1990-1994

| *Year* | *Quadratic* | | *Power* | |
|---|---|---|---|---|
| | *All risks* | *Homosexual* | *All risks* | *Homosexual* |
| *Observed:* | | | | |
| 1984 | 4 | | | |
| 1985 | 9 | 1 | | |
| 1986 | 20 | 7 | | |
| 1987 | 43 | 25 | | |
| 1988 | 95 | 64 | | |
| 1989 | 151 | 107 | | |
| *Projected:* | | | | |
| 1990 | 235.3 | 167.0 | 213.3 | 213.2 |
| 1991 | 346.7 | 242.2 | 290.7 | 384.0 |
| 1992 | 489.0 | 333.6 | 384.4 | 643.8 |
| 1993 | 666.0 | 442.2 | 495.6 | 1,021.9 |
| 1994 | 881.6 | 569.0 | 625.5 | 1,552.7 |

*Conclusions*

1. The quadratic and power equations provided the best fit of the epidemic of AIDS in Costa Rica.

2. The quadratic equation gave the most likely projections of AIDS due to all risks, for the quinquenium 1990-1994.

3. An underestimation of the epidemic by the power curve in the past probably was due to the small number of cases.

4. There seems to have been greater under reporting in 1989 than in preceding years, probably due to difficulties in diagnosis, migration of cases outside the country, seclusion of cases fearing discrimination and mistreatment

hospitals, and treatment with zidovudine.

5. Under reporting likely diminished the potential of modulation by the quadratic and power curves.

6. Estimation of the AIDS epidemic in small countries is trickier than in large industrialized nations that have excellent notification systems and which are experiencing large AIDS epidemics. However, the exercise is useful and necessary to determine public health priorities for health policy, planning and management.

7. The AIDS epidemic will have great impact on the availability and cost of medical services and other health care supporting systems. It will also be evident on the national socioeconomic situation.


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