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Prediction of world records in athletics and swimming by a time-series analysis

Nelson, Marilyn Ruth

THE PREDICTION OF WORLD RECORDS IN ATHLETICS AND SWIMMING BY A TIME-SERIES ANALYSIS

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Abstract

In an age of a flourishing emphasis on sports and a high frequency of individual record breaking, a detailed description of performance trends would provide a better understanding of what might happen in the future. In this study, world records in swimming and athletics were analyzed to relate the time of occurrence to their magnitude in order to predict future record performances. Records were considered from 1945 or the earliest date after 1945, to 1977 and subjected to a time-series analysis (Box-Jenkins method) to determine predicted values for 1978 through 1984. Predictions and their confidence limits were developed for all events. A 5% error rate was considered as the widest acceptable degree of error. Only some track events fell within this criterion range and therefore, contained adequate predictions. Swimming and field events were mainly unacceptable in light of the predictions which were made. Several varibles affecting predictions were discussed. Otherwise the prediction of world record performance trends in swimming, track, and field was found to be unsatisfactory when world records served as source data.

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INTRODUCTION

Statement of the Problem

The purpose of this thesis was to relate the time of occurrence to the magnitude of world record performances in the sports of swimming and athletics (track and field) since 1945.

Significance of the Study

The Olympic motto: citius, altius, fortius, which means faster, higher, and stronger, describes the intentions behind the winning performances of the past Olympic games. Athletes and coaches are continually seeking new methodologies to produce increased performances. With an ability to accurately predict the trends in performance improvement, athletes and coaches could define training regimes with greater precision and expectations.

Predicted performances might serve as a guideline for an individual athlete in setting successive goals for competition. Such predictions would also act as guides for both physical and mental characteristics of performance.

The present method for understanding performance trends has been one of "hindsight" and educated guesses by trainers and coaches. At various times intellectuals have attempted to define the upper limits of performance only to be eventually discredited by an athlete's feat. A detailed description of performance trends would allow for a better understanding of what will happen in the future. It is possible that with the burgeoning emphasis on sports and the rapidity of individual record breaking that changes in rates as cycles of performance improvements might exist. If this is so, and it could be described, then national sporting associations could establish long-term target performances for various programmes. It would be feasible to orient the long-term goals of athletes towards realistic and necessary training and dedication demands if this information was known.

Some attempts have been made at predicting record breaking trends. They have been somewhat simple and inaccurate. The application of advanced prediction techniques could improve the hithertofore unsatisfactory area of study.

This thesis will attempt to provide vital information for the decision making purposes of two sports. It will also endeavor to advance a technique of study, that of predicting trends in world sporting records.

Delimitations

This study uses world records from athletics and swimming from 1945. The records in athletics are for out-door competition only. There are some events that originated later than 1945, e.g., the 100 metre Butterfly for men, etc. These will be indicated in the discussion of results.

In order to obtain an accurate prediction, several swimming events are dated later than 1945. This is due to the acceptance of records set only in a 50 metre Bath, and the establishment of consistency in a stroke.

Limitations

1. This study was limited to the use of the Box-Jenkins

approach of time-series analysis.

2. The Box-Jenkins time-series design requires a data point (world record) for each month of the years involved. A value is repeated until a new data point (record) occurs. However, if there is more than one value in a single month, the best performance for that month is recorded. Because of the little change in records in the running events, a quarterly value was used.

3. Innovations, such as the introduction of the fibre-glass pole in the pole vault, and interventions, such as wars, will cause a variability in athletic performance.

Definitions

Stationarity is based on the assumption that a process is in a particular state of statistical equilibrium.

Autocorrelation-Autocovariance help describe the evolution of a process through time. The stationarity assumption also implies that the joint probability distribution $p(z_{t_1}, z_{t_2})$ is the same for all times t_1, t_2, which are a constant interval apart. It follows that the nature of this joint distribution can be inferred by plotting a scatter diagram using pairs of values (z_t, z_{t+k}), of the time-series, separated by a constant interval or *lag k*. The autocorrelation at *lag k* is

$$\rho_k = \frac{E[(z_t-\mu)(z_{t+k}-\mu)}{\sqrt{E[(z_t-\mu)^2] E[(z_{t+k}-\mu)^2]}}$$

$$= \frac{E[(z_t-\mu)(z_{t+k}-\mu)]}{\sigma_z^2}$$

The covariance between z_t and its value z_{t+k}, separated by k intervals of time, is called *autocovariance* at *lag k* and is defined by

$$\gamma_k = \text{cov}[z_t, z_{t+k}] = E[(z_t - \mu)(z_{t+k} - \mu)]$$

Since, for a stationary process, the variance $\sigma_z^2 = \gamma_o$ is the same at time t+k as at time t, the autocorrelation at *lag k* is $\rho_k = \frac{\gamma_k}{\gamma_o}$ (Box-Jenkins, 1970; pp. 26-28).

Partial Autocorrelation Function is a device which exploits the fact that whereas an AR(p) process has an autocorrelation function which is infinite in extent, it can be described in terms of *p* non-zero functions of the autocorrelations. Denoted by Φ_{kj}, the jth coefficient in an autoregressive process of order k, so that Φ_{kk} is the last coefficient. The Φ_{kj} satisfy the set of equations

$$\rho_k = \Phi_{k1}\rho_{j-1} + \dots + \Phi_{k(k-1)}\rho_{j-k+1} + \Phi_{kk}\rho_{j-k} \qquad j=1,2,\dots,k$$

(Box-Jenkins, 1970; p. 64).

Differencing is a special type of filtering which is particularly useful for removing a trend. It is simply to difference a given time-series until it becomes stationary. For non-seasonal data, first-order differencing is usually sufficient to attain apparent stationarity, so the new series $\{y_1, \dots, y_{n-1}\}$ is formed from the original series by

$$y_t = X_{t+1} - X_t = \nabla X_{t+1}$$

Second-order differencing is required using the operator ∇^2 where

$$\nabla^2 X_{t+2} = \nabla X_{t+2} - \nabla X_{t+1} = X_{t+2} - 2X_{t+1} + X_t$$

(Chatfield, 1975; p. 21).

Autoregression is the current value of the process and is expressed as a finite, linear aggregate of a *previous value of the process* and a shock a_t. The values of a process are at equally spaced times t, t-1, t-2,... by z_t, z_{t-1}, z_{t-2}... $\tilde{z}_t$, $\tilde{z}_{t-1}$, $\tilde{z}_{t-2}$ are the deviations from μ, i.e., $\tilde{z}_t = z_t - \mu$, then $\tilde{z} = \Phi_1\tilde{z}_{t-1}+\Phi_2\tilde{z}_{t-2}+\ldots+\Phi_p\tilde{z}_{t-p}+a_t$ is called an autoregressive (AR) process of order *p* (Box-Jenkins, 1970; pp. 9.-10).

Moving Average is when $\tilde{z}_t$ is linearly dependent on a finite number *q* of previous a's (AR)

$$\tilde{z} = a_t - \Theta_1 a_{t-1} - \Theta_2 a_{t-2} - \ldots - \Theta_q a_{t-q}.$$

The weights 1, $-\Theta_1$, $-\Theta_2, \ldots, -\Theta_q$ are used to multiply the parameters (a's). They do not need to total one nor do they need to be positive (Box-Jenkins, 1970; p. 10).

Correlogram is an aid in interpreting a set of autocorrelation coefficients. It is a graph on which r_k is plotted against the *lag* *k* (Chatfield, 1975). Figure 1 is an example of a correlogram plotting swimming world records for the men's 100 metre Free-style.

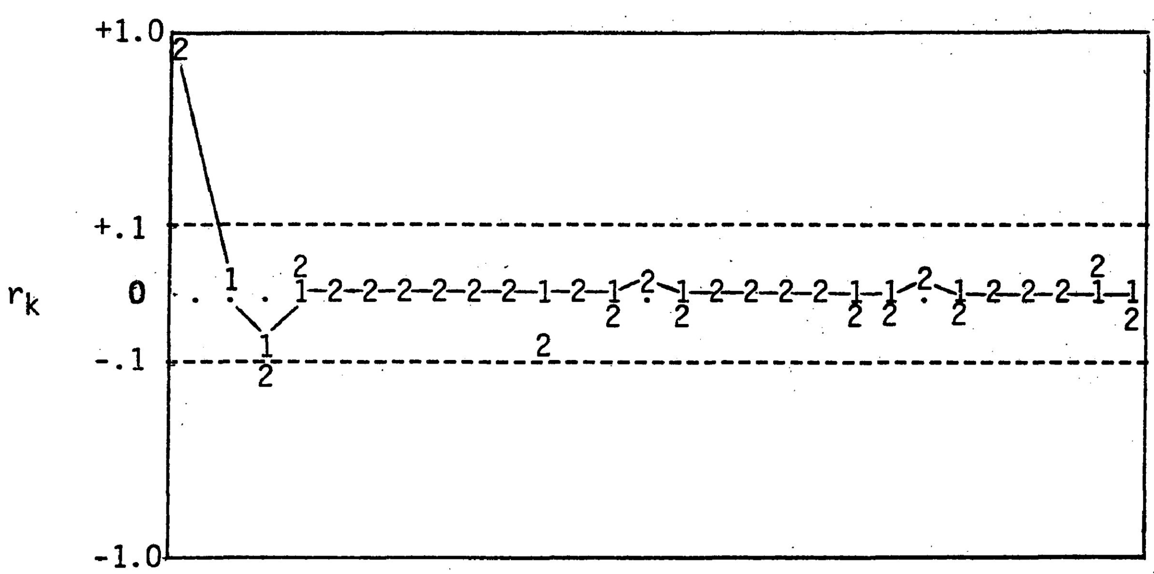

Figure 1. A correlogram showing first and second-order autocorrelations for the men's 100 metre Free-style. The first-order correlations are indicated by a "1", the second-order correlations are indicated by a "2" when the autocorrelation coefficient is plotted against lag k.

Chapter II

REVIEW OF LITERATURE

Others have conducted studies using mathematical equations in an effort to make predictions concerning athletic performances. Lietzke (1956) formulated the equation: $W=aB_w 2/3$, where W is the weight lifted, a is a constant, and B_w is body weight, in a study of weight lifting. As a logarithmic expression it is written: $\log W=2/3 \log B_w + \log a$. When log W is plotted against log B_w the plot is linear, with a slope of approximately 2/3 or 0.67. Using this method, a single lift or combination score of lifts could be predicted for a trained weightlifter in a single event.

Following the assumptions of Lietzke, Karpovich (1968), formulated a new equation: $\log W=1.4718 + .6748 \log B_w$ to compensate for the breaking of records during the period 1958 to 1964 Olympics. Results of predicted versus actual records for 1964, indicated that some scores reached the predicted record values, however, all the scores in 1964 were greater than the actual scores for 1963. After the breaking of the records in 1964 the constant in the equation again needed to be revised to allow for the improvement of scores in 1965.

With this method, predictions were based on a one year or one competition score, i.e., a single data point. Collected records from several competitions or longitudinal data covering a number of years cannot be fitted into these equations to predict performances well into the future. In addition, this method does not facilitate looking at past performances to detect trends or cycles.

Frucht and Jokl (1964) found that when dealing with athletics and swimming, events are subject to influences of training and chance. Therefore, in the computing of trends they used a curve of "best fit", which followed polynomial limitations. They felt that with a polynomial function future trends may be identified through the limits of time and precision, not chance. Also, it is now possible to predict ranges of performance growth, and lastly to predict future world and Olympic performances from past world and Olympic records.

To compare predicted athletic performances, the differences around each mean value for an event were expressed in multiples of standard deviations. If actual performances were greater or less than 2σ, it was concluded that factors dealing with training or new equipment were the cause.

The results of predictions made by Frucht and Jokl for the 1964 Tokyo Olympics winners, were found to lie within a standard deviation of one σ (in 23 of 34 events) and the remaining 11 events were found to lie within 2.5σ. This indicates a large amount of error in the range for predicted values.

Jokl and Jokl (1968, 1976) expanded upon the method of predicting athletic records based on curve fitting. A polynomial to the fourth degree was calculated showing record growth in swimming and a second degree polynomial gave them the best fit for athletics. They suggested that one can never predict the exact performance of a single athlete with this method, although a close estimation may be achieved.

Winning trends in Olympic competition were detected by Stefani (1977). Data were taken from Olympic records 1952-1976 in athletics and swimming. Using a computer analysis method of "least squares", a straight line was fitted through a scatter of points. When computed a multiplying factor expressed improvement by the percent of which times were reduced or lengths increased. Predictions were calculated for the 1980 and 2000 Olympic games. No mention of an amount of error or a range for the values was made.

Time-series designs have been used in studies of economics, which involve looking at cyclic behaviour of a particular economy (Praetz, 1974). Accounting income (Brode and Buckmaster, 1976), and marketing research (Moriarty, 1975) are fields which have used time-series analyses to make predictions.

The Box-Jenkins (1970) approach has been successfully used by Helner and Johansson (1977) in the field of advertising-sales relationships. Data were collected on past sales and marketing variables to obtain a prediction (forecast) and indicate the most effective measures for the future. Lorek, McDonald, and Patz (1976) also used the Box-Jenkins approach to forecast earnings in management.

The Box-Jenkins approach estimates an autocorrelation function taken from observations in time to detect patterns, which may be contained in the data. After the identification process, estimations of the values of parameters are made, and verified to determine a model of "best fit". If tests show a poor or no fit the procedure suggests how to modify the model and return to identification, estimation, and verification (Anderson, 1975).

The literature disclosed several attempts to predict athletic performances. It also indicated a desire for a more accurate method of prediction. It is hypothesized that the Box-Jenkins approach of a time-series design will produce a more exact method of prediction for athletic performances.

Chapter III

METHODOLOGY

The Box-Jenkins Approach: Time-Series Design

The following statistical methodology was used in this study.

The procedure is a model by G.E.P. Box and G.M. Jenkins (1970) consisting of two sections, APCORR and TYMPAC, both of which originate from Queen's Statistics Council, Queen's University, Kingston, Ontario, Canada.

APCORR is the first and main programme and contains five subroutines. In this routine the autocorrelations and partial autocorrelation coefficients are computed and plotted for a single data series.

Next, subroutine GRAPHL plots graphs of a series of functions. Once graphed, subroutine PARTIA creates a "Laurent" matrix using correlations that were evaluated in the main programme. This matrix is used as input for subroutines DELTA and SOLVEQ, which together evaluate and store the partial correlations. In subroutine DELTA, calculations are made for the determinant of a matrix, which is then broken down into an upper triangular form. Once the matrix is in the triangular form, subroutine SOLVEQ solves the partial correlations. Finally, CONVT converts the values in the original array *X* by logarithmic transformation.

The second section consists of TYMPAC. The previously calculated data are taken through a series of autoregressions to produce predicted values from the differences between the various record performances.

The autoregression coefficient and moving average are employed to difference the data in a repeated process until the data are stationary. As Chatfield explained:

> This [stationarity] is achieved by examining the correlograms of various differenced series until one is found which comes down to zero 'fairly quickly' and from which any seasonal effect has been largely removed. (1975, p. 90)

In this study first-order differencing is employed and does not use the first and last data points on the basis that two surrounding values are not available for computation. Once these values have been subtracted, actual and predicted differencing are calculated to obtain a "goodness-of-fit". Finally, predicted values and ranges are printed along with an actual score (if one is available).

Data

Data were collected from the following sources. 1. Swimming: The Encyclopaedia of Swimming; The World Almanac and Book of Facts-1970, 1971, 1972, 1973; Information Please Almanac Atlas and Yearbook-1974, 1975, 1976, 1977; Guinness Book of World Records-1978.

2. Athletics: The Encyclopedia of Sports, 5th Edition; The World Almanac and Book of Facts-1948, 1954, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973; Information Please Almanac Atlas and Yearbook-1974, 1975, 1976, 1977; Guinness Book of World Records-1978.

The data werethen converted into seconds or metric units and placed on computer cards along with the data of each record performance. Beginning January 1, 1945 (unless specified) a value is repeated until a new data point (record) occurs. However, if there is more than one value in a single month, the best performance for that month will be value in a single month, the best performance for that month will be recorded.

<u>Preliminary Investigations</u>

First, in an attempt to replicate the study of Jokl and Jokl (1964) a Fortran IV, subroutine GEPLSD programme was obtained. In this pilot study a fitted tenth degree polynomial for arbitrary data in the high jump was calculated to check the degree of error in the sum of the squares of the deviations. This programme was rejected on the basis that the sum of the squares of the deviations was 2.2348, indicating there was still a great amount of error in the calculations for predicting values.

Secondly, the same data were placed in a time-series design, the Box-Jenkins approach, to test its effectiveness for prediction. There were 360 values, the first and last values were lost to first-order differencing. One value is subtracted out for autoregression and the last nine were taken out for future scores. Once these values were subtracted out, actual and predicted differencing were calculated to obtain a "good fit". Then the predicted values and ranges were printed out.

The sum of squares after the final regression was 7.77, with the relative change in each parameter less than .004. A graph is then formed showing the calculated function values and the observed data if different from the calculated value. An approximate 95 percent limit for the correlations was determined to be ± 1.07. Table 1 and Figure 2 shows the forecasts (predictions) for nine periods into the future giving a lower confidence limit, upper confidence limit,

Table 1

Forecast Print-Out and Evaluation

ITEM 1 FORECASTS AT BASE PERIOD352

PERIODS AHEAD	LOW CONF. LIMIT	FORECAST	UP. CONF. LIMIT	ACTUAL, IF KNOWN
1	88.3	88.6	88.9	88.5
2	88.3	88.7	89.1	88.5
3	88.3	88.9	89.4	88.5
4	88.4	89.0	89.6	88.5
5	88.4	89.1	89.8	88.5
6	88.5	89.2	89.9	88.5
7	88.6	89.3	90.1	88.5
8	88.6	89.5	90.3	88.5
9	88.7	89.6	90.5	88.5

ERROR EVALUATION
* * * * * * * *

ACTUAL DEMAND	HIGH SIDE ERROR	MEAN ERROR	LOW SIDE ERROR
88.5	0.2	-0.1	-0.4
88.5	0.2	-0.2	-0.6
88.5	0.2	-0.4	-0.9
88.5	0.1	-0.5	-1.1
88.5	0.1	-0.6	-1.3
88.5	0.0	-0.7	-1.4
88.5	-0.1	-0.8	-1.6
88.5	-0.1	-1.0	-1.8
88.5	-0.2	-1.1	-2.0

NOTE: HIGH SIDE ERROR IS ACTUAL DEMAND - LOWER CONFIDENCE LIMIT
MEAN ERROR (DEMAND - FORECAST)
LOW SIDE ERROR IS (DEMAND - UPPER CONFIDENCE LIMIT).

END OF TYMPAC RUN
FOR ITEM 1

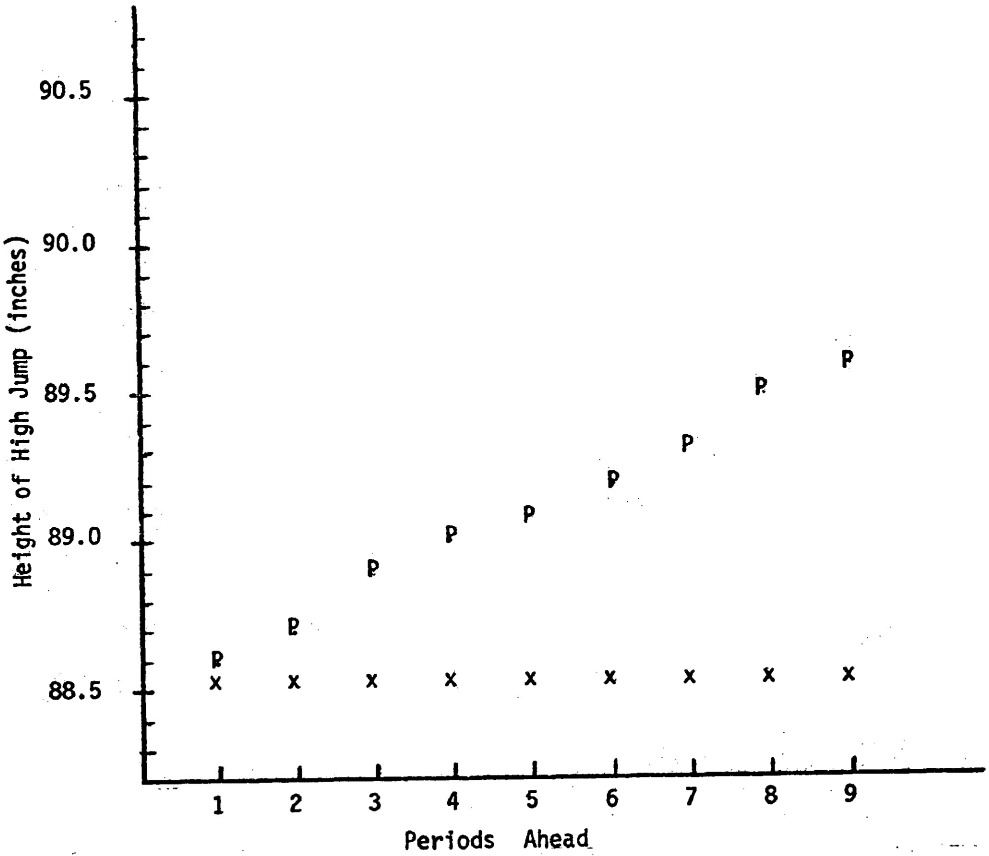

Figure 2 An example of predicted versus actual scores for nine periods ahead (P=predicted, x=actual).

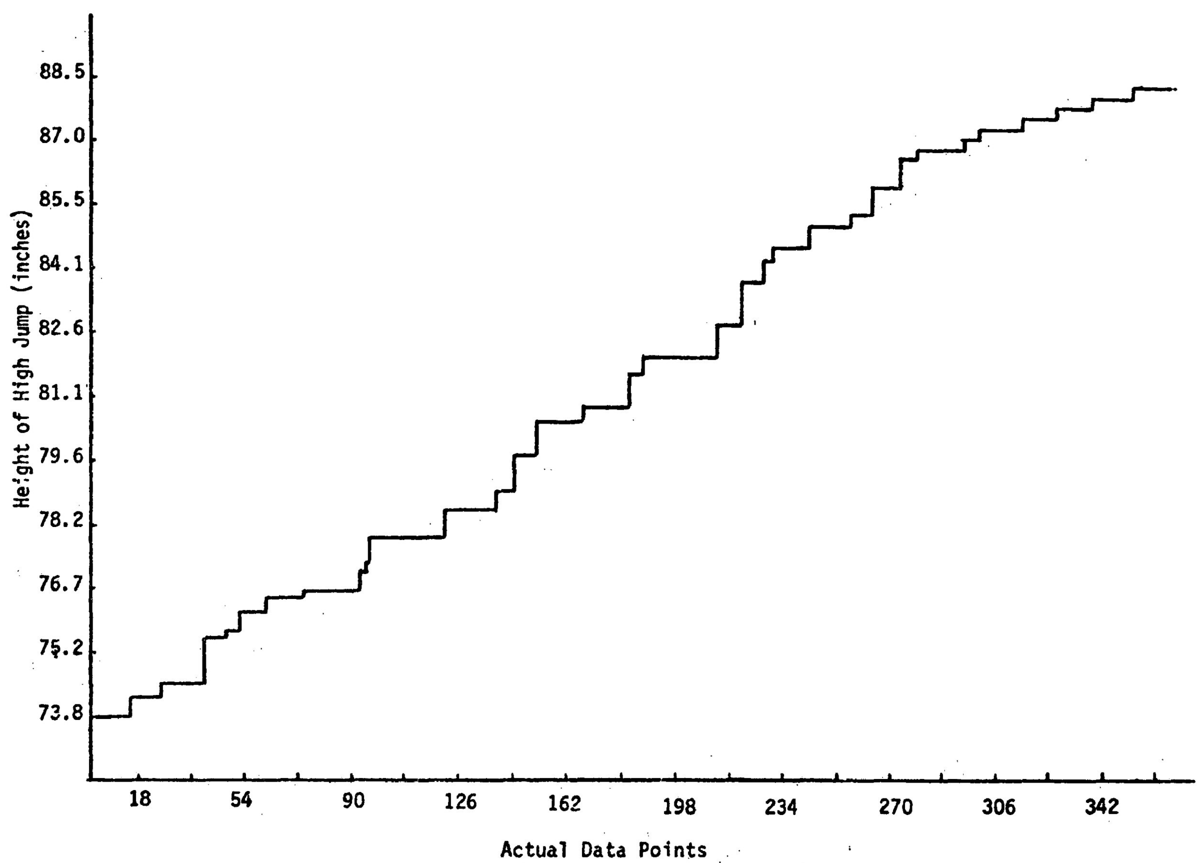

Figure 3 An entire plot of arbitrary data for the High Jump.

predicted value, and the actual value.

It would appear, from the sum of the squares, that the time series programme would not be as accurate as the polynomial equation. But in actuality, it gives more information about the data. It indicates the differences in magnitude between the records, besides giving upper and lower confidence limits, and an approximate 95 percent confidence limit for the correlations. All of these make for a more exact prediction method.

Data Output Explanation

The data output contains two determined initial parameters. For this pilot study they are (1) .8, and (2) 1.0. The process that follows is a series of iterations of the autoregressive process, differencing the data, giving a sum of squares after each regression. When the relative change in each parameter is less than .004 (which is the predetermined value given by this programme) the regression process stops and the parameter values are given which were determined through regression.

The final function values are then listed. These are the values determined by regression and the initial value. Next listed are the residuals. These are an estimate of individual value variations, "where the residuals are the difference between the observations and the corresponding values of the fitted curve" (Chatfield, 1975; pp. 16, 17). In this instance the variance of the residuals equals .2232, with 348 degrees of freedom. Individual confidence limits for each parameter are given, followed by the approximate confidence limits for each function value. The function values and observed data (if not the same) are then presented for each of the 350 values.

For this study, the last eight values were not included in the function values. Instead, these values were used to check the reliability of the functional values. The error evaluation table indicates the accuracy of prediction versus the actual demand.

The time-series design through its combinations of identification, estimation, and verification gives a more thorough description of the data. The correlograms provide a visual description of the data in auto- and partial correlations. Finally, TYMPAC calculates function values to compare with the data and will give forecasts for intervals of time determined by the investigator.

Decision Criteria for Acceptable Predictions

For a prediction to be deemed acceptable one criterion had to be met. The percentage of difference between the appropriate confidence limit and the event prediction was not to exceed five percent of the event prediction. This value was chosen by the author to partly reflect the traditional five percent level of significance. Although the decision making process in this study was not comparable to the more common method of determining significance, it did produce a consistent decision making standard.

Chapter IV

RESULTS AND DISCUSSIONS

Results

The purpose of this thesis was to determine if a statistical prediction from a history of world records was a useful procedure.

Track events were the only events which displayed a consistent history of record development to serve as a basis for predicting new world records. Although error was included in every prediction, the rate of improvement that was indicated in these results offered a reasonable basis for setting future target performances in track events. This contrasted markedly with field and swimming events. Their highly variable and inconsistent patterns of record breaking indicated that record breaking in these events could not be predicted upon performance alone. Statistical prediction was not useful with these events.

Table 2 summarizes this writer's assessment of the degree of acceptability of the amounts of error for each prediction. For Men's swimming two out of sixteen predictions were acceptable whereas none were acceptable for the fifteen Women's swimming events. For both Men's and Women's track only one event, the Women's 400 metres, out of seventeen events was unacceptable. Three out of thirteen field events were acceptable.

Tables 3 through 8 indicate the predicted performances in each event at six month intervals from January 1978 to June 1984. Graphs of past and predicted performances for every event are included in

Table 2

Summary By Event of Prediction, Confidence Limits and Decision of Acceptability

EVENT	PREDICTION	CONFIDENCE LIMIT	%DIFF.	DECISION
Men's Swimming	Min./Sec./Tenths			
100 m Free	49.4	45.9	7.09	unacceptable
200 m Free	1:40.7	1:35.2	5.46	unacceptable
400 m Free	3:18.9	3:07.7	5.63	unacceptable
800 m Free	7:04.3	6:29.4	8.23	unacceptable
1,500 m Free	12:29.1	11:14.5	9.96	unacceptable
4 x 100 m Free	3:07.5	2:59.1	4.48	acceptable
4 x 200 m Free	6:21.7	5:57.4	6.37	unacceptable
4 x 100 m Medley	3:42.2	3:27.8	6.48	unacceptable
100 m Breast	57.8	53.0	8.31	unacceptable
200 m Breast	2:06.9	1:57.7	7.25	unacceptable
100 m Fly	48.5	44.6	8.04	unacceptable
200 m Fly	1:46.1	1:38.2	7.45	unacceptable
100 m Back	49.1	46.6	5.09	unacceptable
200 m Back	1:59.2	1:51.8	6.21	unacceptable
200 m I.M.	2:03.7	1:58.0	4.61	acceptable
400 m I.M.	4:23.7	4:01.5	9.11	unacceptable
Women's Swimming				
100 m Free	52.4	49.7	5.15	unacceptable
200 m Free	1:53.2	1:46.0	6.36	unacceptable
400 m Free	4:08.9	3:52.6	6.55	unacceptable
800 m Free	6:54.3	6:14.9	13.39	unacceptable
1,500 m Free	13:22.5	12:02.8	10.18	unacceptable

Table 2 (cont'd)

EVENT	PREDICTION	CONFIDENCE LIMIT	% DIFF.	DECISION
Women's Swimming				
4 x 100 m Free	3:21.3	3:06.4	6.94	unacceptable
100 m Breast	67.2	62.8	6.55	unacceptable
200 m Breast	2:26.6	2:17.7	6.07	unacceptable
100 m Fly	56.3	52.9	6.04	unacceptable
200 m Fly	2:11.0	2:00.4	8.09	unacceptable
100 m Back	53.2	48.3	9.21	unacceptable
200 m Back	1:54.4	1:44.6	8.57	unacceptable
200 m I.M.	2:12.2	2:04.5	5.83	unacceptable
400 m I.M.	3:43.0	3:15.0	12.56	unacceptable
4 x 100 m Medley	4:07.9	3:51.2	6.74	unacceptable
Men's Running				
100 m	9.9	9.7	2.02	acceptable
200 m	19.0	18.4	3.16	acceptable
400 m	43.2	42.2	2.32	acceptable
800 m	1:43.0	1:41.3	1.65	acceptable
1,500 m	3:30.6	3:25.5	2.42	acceptable
5,000 m	13:10.6	12:48.7	2.69	acceptable
10,000 m	27:13.7	26:16.0	3.53	acceptable
3,000 m steeple-chase	8:08.0	7:55.6	2.54	acceptable
110 m hurdles	13.0	12.7	2.31	acceptable
400 m hurdles	46.6	45.3	2.80	acceptable
4 x 100 m Relay	38.0	37.0	2.63	acceptable
4 x 400 m Relay	2:56.0	2:50.2	3.30	acceptable

Table 2 (cont'd)

EVENT	PREDICTION	CONFIDENCE LIMIT	% DIFF.	DECISION
Women's Running				
100 m	10.8	10.5	2.78	acceptable
200 m	22.0	21.4	2.73	acceptable
400 m	48.3	44.2	8.49	unacceptable
800 m	1:55.0	1:49.3	4.96	acceptable
4 x 100 m	41.9	40.0	4.54	acceptable
Men's Field Events				
Pole Vault	5.7	6.2	8.78	unacceptable
Discus	81.2	86.5	6.53	unacceptable
Shot Put	24.8	26.9	8.45	unacceptable
Hammer Throw	92.8	99.4	7.11	unacceptable
Javelin	103.3	110.7	7.16	unacceptable
Long Jump	9.0	9.6	6.67	unacceptable
Triple Jump	17.9	18.6	3.91	acceptable
High Jump	2.4	2.5	4.17	acceptable
Women's Field Events				
Discus	80.7	88.8	10.04	unacceptable
Shot Put	26.7	29.5	10.49	unacceptable
Javelin	72.9	81.0	11.1	unacceptable
Long Jump	7.2	7.6	5.56	unacceptable
High Jump	1.9	1.9	.00	acceptable

Table 3

Men's Athletics - Field Events - Predicted Records

EVENTS	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Pole Vault	5.7M*	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	5.7M+	5.7	5.8	5.8	5.9	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1	6.2
Long Jump	8.8M*	8.8	8.8	8.8	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	9.0
	8.9M+	9.0	9.0	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6
Discus	70.4M*	70.9	71.7	72.3	73.2	73.8	74.6	75.5	76.5	77.2	78.3	79.3	80.3	81.2
	70.9M+	72.1	73.5	74.5	75.8	76.7	77.9	79.0	80.4	81.4	82.8	84.1	85.4	86.5
Shot Put	21.8M*	22.0	22.2	22.4	22.6	22.8	23.0	23.3	23.5	23.7	24.0	24.3	24.6	24.8
	22.0M+	22.5	22.9	23.3	23.6	23.9	24.3	24.6	25.0	25.4	25.7	26.1	26.5	26.9
Triple Jump	17.7M*	17.7	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.9	17.9
	17.8M+	17.9	18.0	18.1	18.2	18.2	18.3	18.3	18.4	18.4	18.5	18.5	18.6	18.6
Hammer Throw	78.8M*	79.5	80.5	81.4	82.4	83.4	84.5	85.5	86.7	87.9	89.1	90.4	91.7	92.8
	79.4M+	80.9	82.7	84.1	85.6	87.0	88.4	89.9	91.4	93.0	94.6	96.2	97.9	99.4
High Jump	2.3M*	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4
	2.3M+	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.5	2.5
Javelin	93.9M*	94.4	95.1	95.6	96.4	96.9	97.7	98.4	99.2	99.9	100.8	101.7	102.5	103.3
	94.6M+	96.1	97.6	98.7	100.0	101.0	102.3	103.3	104.7	105.7	107.1	108.4	109.6	110.7

* Predicted Value
+ Upper Confidence Limits

Table 4

Women's Athletics - Field Events - Predicted Records

EVENTS	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Long Jump	6.9M*	6.9	7.0	7.0	7.0	7.0	7.1	7.1	7.1	7.1	7.2	7.2	7.2	7.2
	7.0M+	7.0	7.1	7.1	7.2	7.3	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.6
High Jump	1.9M*	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	1.9M+	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Discus	70.0M*	70.6	71.4	72.1	72.8	73.6	74.4	75.1	76.0	76.9	77.8	78.7	79.7	80.7
	70.8M+	72.4	74.2	75.5	76.8	78.1	79.4	80.4	82.0	83.3	84.6	86.0	87.4	88.8
Shot Put	22.2M*	22.4	22.7	23.0	23.3	23.7	24.0	24.4	24.7	25.1	25.5	25.9	26.2	26.7
	22.4M+	23.0	23.7	24.2	24.7	25.2	25.7	26.2	26.7	27.3	27.8	28.4	29.0	29.5
Javelin	68.6M*	68.8	69.2	69.5	69.8	70.1	70.5	70.8	71.1	71.5	71.8	72.2	72.5	72.9
	69.4M+	70.9	72.2	73.2	74.1	74.9	75.7	76.5	77.3	78.0	78.8	79.5	80.3	81.0

* Predicted Value

\+ Upper Confidence Limits

Table 5

Men's Athletics - Running Events - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
100 metres	9.9s*	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
	9.9s+	9.9	9.9	9.9	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.7	9.7
200 meters	19.5s*	19.5	19.4	19.4	19.3	19.3	19.2	19.2	19.2	19.1	19.1	19.1	19.0	19.0
(straight)	19.4s+	19.3	19.2	19.1	19.1	19.0	18.9	18.8	18.8	18.7	18.6	18.6	18.5	18.4
400 meters	43.8s*	43.8	43.7	43.7	43.7	43.6	43.6	43.5	43.5	43.4	43.4	43.3	43.2	43.2
	44.0s+	43.5	43.4	43.3	43.2	43.0	42.9	42.8	42.7	42.6	42.5	42.4	42.3	42.2
800 meters	1:43.4*	1:43.4	1:43.4	1:43.3	1:43.3	1:43.3	1:43.2	1:43.2	1:43.2	1:43.2	1:43.1	1:43.1	1:43.0	1:43.0
	1:43.1+	1:42.8	1:42.7	1:42.5	1:42.4	1:42.2	1:42.1	1:42.0	1:41.9	1:41.8	1:41.6	1:41.5	1:41.4	1:41.3
1,500 meters	3:32.1*	3:32.0	3:31.9	3:31.8	3:31.7	3:31.5	3:31.4	3:31.3	3:31.2	3:31.0	3:30.9	3:30.8	3:30.7	3:30.6
	3:31.4+	3:30.7	3:30.1	3:29.6	3:29.2	3:28.7	3:28.3	3:27.9	3:27.5	3:27.1	3:26.7	3:26.3	3:25.9	3:25.5
5,000 meters	13:12.8*	13:12.6	13:12.4	13:12.2	13:12:0	13:11.9	13:11.7	13:11.5	13:11.4	13:11.2	13:11.1	13:10.9	13:10.8	13:10.6
	13:09.6+	13:06.9	13:04.9	13:03.1	13:01.4	12:59.8	12:58.3	12:56.9	12:55.4	12:54.0	12:52.7	12:51.3	12:50.0	12:48.7
10,000 meters	27:29.9*	27:28.6	27:27.3	27:26.1	27:24.8	27:23.6	27:22.3	27:21.1	27:19.8	27:18.6	27:17.4	27:16.1	27:14.9	27:13.7
	27:20.6+	27:12.4	27:06.1	27:00.5	26:55.4	26:50.6	26:46.0	26:41.5	26:37.1	26:32.8	26:28.5	26:24.3	26:20.2	26:16.0

* Predicted Values

\+ Lower Confidence Limits

Table 5 (con't)

Men's Athletics - Running Events - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June. 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
20,000 metre	1:23:16.2*	1:22.43.7	1:22:09.5	1:21:33.5	1:20:55.6	1:20:15.7	1:19:33.8	1:18:49.8	1:18:03.4	1:17:14.6	1:16:23.3	1:15:29.3	1:14:32.6	1:13:32.9
(walk)	1:22:27.8+	1:21:18.9	1:20:18.7	1:19:20.8	1:18:23.2	1:17:25.2	1:16:25.9	1:15:25.2	1:14:22.6	1:13:17.9	1:12:10.9	1:11:11.1	1:09:48.6	1:08:33.1
50,000 metre	3:56:08.1*	3:55:06.5	3:54:03.2	3:52:58.1	3:51:51.1	3:50:42.3	3:49:31.4	3:48:18.6	3:47:03.6	3:45:46.6	3:44:27.3	3:43:05.8	3:41:41.9	3:40:15.7
(walk)	3:53:50.7+	3:51:06.0	3:48:49.1	3:46:42.1	3:44:39.7	3:42:39.6	3:40:40.4	3:38:41.3	3:36:41.5	3:34:40.6	3:32:38.4	3:30:34.4	3:28:28.5	3:26:20.4
3,000 metre	8:08.0*	8,08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0	8:08.0
Steeplechase	8:06.6+	8:06.4	8:03.0	8:01.9	8:01.0	8:00.0	7:59.6	7:58.8	7:58.2	7:57.6	7:57.1	7:56.5	7:56.0	7:55.6
110 metre	13.1*	13.1	13.1	13.1	13.1	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Hurdles	13.0+	13.0	13.0	12.9	12.9	12.9	12.8	12.8	12.8	12.8	12.7	12.7	12.7	12.7
400 metre	47.4s*	47.4	47.3	47.3	47.2	47.2	47.1	47.1	47.0	46.9	46.8	46.8	46.7	46.6
Hurdles	47.2s+	47.0	46.8	46.7	46.5	46.4	46.3	46.1	46.0	45.9	45.7	45.6	45.5	45.3
4 x 100 metre	38.2s*	38.2	38.1	38.1	38.1	38.1	38.1	38.1	38.0	38.0	38.0	38.0	38.0	38.0
Relay	38.0s+	37.9	37.8	37.7	37.6	37.5	37.5	37.4	37.3	37.3	37.2	37.1	37.1	37.0
4 x 400 metre	2:56.1	2:56.1	2:56.1	2:56.1	2:56.1	2:56.1	2:56.1	2:56.1	2:56.1	2:56.0	2:56.0	2:56.1	2:56.0	2:56.0
Relay	2:55.1+	2:54.3	2:53.7	2:53.3	2:52.9	2:52.5	2:52.2	2:51.8	2:51.5	2:51.2	2:51.0	2:50.7	2:50.5	2:50.2

* Predicted Values

\+ Lower Confidence Limits

TABLE 6

Women's Athletics - Running Events - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
100 metres	10.9s*	10.9	10.9	10.9	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
	10.8s+	10.8	10.8	10.7	10.7	10.7	10.7	10.6	10.6	10.6	10.6	10.6	10.6	10.5
200 metres	22.2s*	22.2	22.2	22.1	22.1	22.1	22.1	22.1	22.1	22.0	22.0	22.0	22.0	22.0
	22.1s+	22.0	22.0	21.9	21.8	21.8	21.7	21.7	21.6	21.6	21.5	21.5	21.4	21.4
400 metres	49.3s*	49.2	49.1	49.0	49.0	48.9	48.8	48.7	48.7	48.6	48.5	48.5	48.4	48.3
	48.5s+	47.9	47.5	47.1	46.7	46.4	46.1	45.8	45.5	45.2	45.0	44.7	44.4	44.2
800 metres	1:55.0*	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0	1:55.0
	1:53.9+	1:53.1	1:52.5	1:52.1	1:51.7	1:51.3	1:51.0	1:50.7	1:50.4	1:50.2	1:49.4	1:49.7	1:49.5	1:49.3
4 x 100 metres	42.5s*	42.4	42.4	42.3	42.3	42.2	42.2	42.1	42.1	42.1	42.0	42.0	41.9	41.9
	42.2s+	41.9	41.7	41.5	41.3	41.2	41.0	40.8	40.7	40.6	40.4	40.3	40.1	40.0

* Predicted Values

\+ Lower Confidence Limits

Table 7

Men's Swimming - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Free-style	49.4s*	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4
100 metres	49.2s+	48.8	48.5	48.2	47.9	47.7	47.5	47.2	47.0	46.8	46.6	46.4	46.1	45.9
200 metres	1:50.2*	1:49.7	1:49.0	1:48.4	1:47.8	1:47.1	1:46.4	1:45.7	1:44.9	1:44.1	1:43.3	1:43.5	1:41.6	1:40.7
	1:49.7+	1:48.5	1:47.2	1:46.2	1:45.2	1:44.1	1:43.1	1:42.1	1:41.0	1:39.9	1:38.8	1:37.6	1:36.4	1:35.2
400 metres	3:51.2*	3:49.6	3:47.2	3:45.0	3:42.8	3:40.5	3:38.1	3:35.6	3:33.1	3:30.4	3:27.7	3:24.9	3:21.9	3:18.9
	3:50.2+	3:47.0	3:43.3	3:40.4	4:37.3	3:34.3	3:31.3	3:28.1	3:24.9	3:21.7	3:18.3	3:14.9	3:11.3	3:07.7
800 metres	8:00.9*	7:57.9	7:53.6	7:49.7	7:45.8	7:41.7	7:37.5	7:33.2	7:28.7	7:24.1	7:19.4	7:14.5	7:09.5	7:04.3
	7:57.7	7:49.9	7:41.6	7:35.0	7:28.7	7:22.3	7:16.0	7:09.7	7:03.3	6:56.7	6:50.1	6:43.3	6:36.4	6:29.4
1500 metres	15:00.9*	14:53.2	14:42.0	14:32.1	14:21.7	14:11.0	13.59.8	13:48.3	13:36.2	13:23.8	13:10.9	12:57.4	12:43.5	12:29.1
	14:54.3+	14:36.8	14:17.4	14:01:7	13:46.3	13:30.8	13:15.1	12:59.2	12:42.9	12:26.2	12:09.1	11:51.4	11:33.3	11:14.5
4 x 100	3:21.0*	3:20.2	3:10.2	3:18.2	3:17.3	3:16.3	3:15.3	3:14.2	3:13.2	3:12.1	3:11.0	3:09.9	3:08.7	3:07.5
Relay	3:20.1	3:18.1	3:16.1	3:14.5	3:12.9	3:11.4	3:09.9	3:08.4	3:06.8	3:05.3	3:03.8	3:02.2	3:00.7	2:59.1
4 x 200	7:22.6*	7:19.5	7:15.0	7:11.0	7:06.9	7:02.6	6:58.1	6:53.4	6:48.6	6:43.6	6:38.4	6:33.0	6:27.5	6:21.7
Relay	7:20.5+	7:14.2	7:07.0	7:01.1	6:55.3	6:49.5	6:43.5	6:37.5	6:31.3	6:24.9	6:18.3	6:11.6	6:04.6	5:57.4
Medley Relay	3:42.2*	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2	3:42.2
4 x 100 metres	3:40.9+	3:38.5	3:36.5	3:35.3	3:34.2	3:33.3	3:32.4	3:31.7	3:30.9	3:30.2	3:29.6	3:29.0	3:28.4	3:27.8

* Predicted Values
+ Lower Confidence Limits

Table 7 (con't)

Men's Swimming - Predicted Records

EVENTS	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Breast-Stroke	1:02.8*	1:02.6	1:02.2	1:01.9	1:01.5	1:01.1	1:00.8	1:00.4	1:00.0	59.6	59.2	58.8	58.3	57.8
100 metres	1:02.4+	1:01.5	1:00.6	1:00.0	59.2	58.5	57.9	57.2	56.5	55.9	55.2	54.5	53.7	53.0
200 metres	2:15.0*	2:14.6	2:13.9	2:13.3	2:12.8	2:12.2	2:11.6	2:10.9	2:10.3	2:09.6	2:09.0	2:08.3	2:07.6	2:06.9
	2:14.1+	2:12.3	2:10.6	2:09.2	2:08.0	2:06.8	2:05.7	2:04.5	2:03.4	2:02.3	2:01.1	2:00.0	1:58.9	1:57.7
Butterfly	54.2s*	53.9	53.5	53.1	52.7	52.3	51.8	51.4	50.9	50.5	50.0	49.6	48.9	49.5
100 metres	53.9s+	53.0	52.2	51.5	50.8	50.1	49.5	48.8	48.1	47.4	46.7	46.1	45.3	44.6
200 metres	1:59.1*	1:58.4	1:57.4	1:56.7	1:55.6	1:54.7	1:53.7	1:52.7	1:51.7	1:50.6	1:49.6	1:48.4	1:47.3	1:46.1
	1:58.4+	1:56.6	1:55.0	1:53.5	1:51.8	1:50.6	1:49.1	1:47.7	1:46.2	1:44.5	1:42.9	1:41.4	1:39.8	1:38.2
Back-Stroke	55.4s*	55.1	54.1	54.6	54.2	53.8	53.3	52.8	51.8	51.3	50.7	50.2	49.8	49.1
100 metres	55.2s+	54.5	53.8	53.1	52.5	51.9	51.2	50.6	49.9	49.3	48.6	47.8	47.3	46.6
200 metres	1:59.2*	1:59.2	1:59.2	1:59.2	1:50.2	1:59.2	1:59.2	1:59.2	1:59.2	1:59.2	1:59.2	1:59.2	1:59.2	1:59.2
	1:58.5+	1:57.2	1:56.2	1:55.5	1:55.0	1:54.5	1:54.1	1:53.7	1:53.3	1:53.0	1:52.6	1:52.4	1:52.1	1:51.8
Individual Medley	2:06.0*	2:05.9	2:05.7	2:05.5	2:05.3	2:05.1	2:04.9	2:04.8	2:04.5	2:04.4	2:04.2	2:04.0	2:03.8	2:03.7
200 metres	2:05.6	2:04.7	2:04.1	2:03.5	2:02.7	2:02.2	2:01.6	2:01.1	2:00.5	2:00.0	1:59.4	1:58.9	1:58.5	1:58.0
400 metres	4:23.7*	4.23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7	4:23.7
	4:21.4+	4:17.6	4:14.7	4:12.8	4:11.2	4:09.7	4:08.4	4:07.2	4:06.1	4:05.1	4:04.1	4:03.3	4:02.4	4:01.5

* Predicted Values
\+ Lower Confidence Limits

Table 8

Women's Swimming - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June. 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Free-Style	55.5s*	55.4	55.1	54.9	54.7	54.4	54.2	54.0	53.7	53.5	53.2	52.9	52.7	52.3
100 metres	55.3s+	54.7	54.2	53.8	53.3	52.9	52.5	52.1	51.7	51.3	51.0	50.6	50.1	49.7
200 metres	1:59.5*	1:58.8	1:58.3	1:58.0	1:57.4	1:57.0	1:56.5	1:56.1	1:55.6	1:55.1	1:54.6	1:54.1	1:53.6	1:53.2
	1:58.5+	1:57.0	1:55.6	1:54.8	1:53.7	1:52.7	1:51.9	1:51.1	1:50.1	1:49.3	1:48.4	1:47.6	1:46.7	1:46.0
400 metres	4:08.9*	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9	4:08.9
	4:07.5+	4:04.7	4:02.4	4:01.2	3:59.8	3:58.7	3:57.7	3:56.8	3:56.0	3:55.2	3:54.5	3:54.0	3:53.2	5:52.6
800 metres	8:34.1*	8:29.1	8:21.9	8:16.6	8:08.7	8:01.8	7:54.5	7:46.9	7:39.0	7:30.7	7:22.2	7:11.7	7:03.9	6:54.3
	8:30.6+	8:20.4	8:08.8	8:00.9	7:50.0	7:40.5	7:30.8	7:20.9	7:10.7	7:00.3	6:49.5	6:36.4	6:29.9	6:14.9
1,500	16:22.8*	16:13.8	16:00.6	15:48.8	15:36.6	15:23.9	15:10.7	14:56.9	14:42.7	14:27.8	14:12.4	13:56.4	13:39.8	13:22.5
metres	16:15.7+	15:56.1	15:34.0	15:16.2	14:58.5	14:40.7	14:22.7	14:04.3	13:45.5	13:26.1	13:06.2	12:45.8	12:24.6	12:02.8
4 x 100 m	3:44.6*	3:43.3	3:41.4	3:39.8	3:38.1	3:36.4	3:34.6	3:32.7	3:30.8	3:28.8	3:26.8	3:24.7	3:22.6	3:20.3
Relay	3:43.3+	3:40.0	3:36.6	3:33.9	3:31.2	3:28.6	3:25.9	3:23.3	3:20.6	3:17.8	3:15.1	3:12.2	3:09.3	3:06.4
Breast-	70.8s*	70.6	70.3	70.0	69.8	69.5	69.2	69.0	68.7	68.4	68.1	67.8	67.5	67.2
Stroke 100 metres	70.3s+	69.5	68.7	68.1	67.6	67.0	66.5	65.0	65.5	64.9	64.4	63.9	63.3	62.8
200 metres	2:33.3*	2:32.9	2:32.4	2:31.9	2:31.4	2:30.9	2:30.4	2:29.9	2:29.4	2:28.8	2:28.3	2:27.7	2:27.1	2:26.6
	2:32.4+	2:30.8	2:29.2	2:28.0	2:26.9	2:25.8	2:24.8	2:23.8	2:22.8	2:21.8	2:20.7	2:19.7	2:18.7	2:17.7

* Predicted Values
\+ Lower Confidence Limits

Table 8 (con't)

Women's Swimming - Predicted Records

EVENT	Jan. 1978	June 1978	Jan. 1979	June 1979	Jan. 1980	June 1980	Jan. 1981	June 1981	Jan. 1982	June 1982	Jan. 1983	June 1983	Jan. 1984	June 1984
Butterfly	1:01.2*	1:00.8	1:00.4	1:00.1	59.7	59.3	58.9	58.6	58.1	57.8	57.4	57.0	56.6	56.3
100 metres	1:00.8+	59.8	59.0	58.3	57.7	57.2	56.5	55.9	55.4	54.9	54.3	53.9	53.3	52.9
200 metres	2:11.2*	2:11.2	2:11.1	2:11:1	2:11.1	2:11.1	2:11.1	2:11.1	2:11.1	2:11.1	2:11.1	2:11.1	2:11.0	2:11.0
	2:10.2+	2:08.6	2:07.2	2:06.2	2:05.4	2:04.7	2:04.0	2:03.4	2:02.8	2:02.3	2:01.8	2:01.3	2:00.8	2:00.4
Back-Stroke	1:01.4s*	1:01.0	1:00.4	59.9	59.4	58.8	58.2	57.6	56.9	56.2	55.5	54.8	54.0	53.2
100 metres	1:01.0s+	1:00.0	58.8	58.0	57.1	56.2	55.3	54.4	53.4	52.5	51.5	50.4	49.4	48.3
200 metres	2:12.3*	2:11.4	2:10.0	2:08.8	2:07.6	2:06.3	2:04.9	2:03.6	2:02.1	2:00.7	1:59.2	1:57.6	1:56.0	1:54.4
	2:11.4+	2:09.2	2:06.7	2:04.8	2:02.9	2:01.0	1:59.0	1:57.1	1:55.1	1:53.1	1:51.1	1:49.0	1:46.8	1:44.6
Individual Medley	2:15.8	2:15.6	2:15.2	2:14.9	2:14.6	2:14.4	2:14.1	2:13.8	2:13.5	2:13.3	2:13.0	2:12.7	2:12.4	2:12.2
200 metres	2:15.1+	2:13.7	2:12.5	2:11.6	2:10.7	2:09.9	2:09.2	2:08.5	2:07.8	2:07.1	2:06.4	2:05.8	2:04.1	2:04.5
400 metres	4:42.2*	4:39.4	4:35.4	4:31.7	4:27.8	4:23.7	4:19.5	4:15.0	4:10.3	4:05.4	4:00.2	3:54.8	3:49.0	3:43.0
	4:39.9+	4:33.7	4:26.6	4:20.9	4:15.1	4:09.3	4:03.3	3:57.2	3:50.8	3:44.2	3:37.4	3:30.2	3:22.7	3:15.0
Medley Relay	4:07.9*	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9	4:07.9
4 x 100 metres	4:06.1+	4:03.3	4:01.1	3:59.7	3:58.5	3:57.4	3:56.4	3:55.5	3:54.7	3:53.9	3:53.1	3:52.4	3:51.8	3:51.2

* Predicted Values

\+ Lower Confidence Limits

Appendix A (field events), Appendix B (track), and Appendix C (swimming).

Discussion

For a predicted performance to serve as a guideline for goal setting, predicted values must be completed accurately allowing for only small amounts of error. For this thesis less than five percent was considered acceptable. Unfortunately, because of the lack of stability within many of the swimming and field events few good predictions were obtained in this study.

Error characteristics. Wide ranges of error in prediction are indicated by error amounts and confidence limits. For example, in the Women's Javelin and the Men's Shot Put (Table 2) the amount of error in calculation of the predicted values was determined to be 8.45 and 11.10 percent of the difference between the predicted values and appropriate confidence limits. These, not being less than the statistical limit of five percent, were concluded to contain too much error in the calculation of the predicted values.

Those events having acceptable amounts (less than five percent) of error are exampled by the Men's 100 metres and High Jump (Table 2). These events contained error estimates of 2.02 and 4.17 percent, indicating greater accuracy in the predicted values.

Predictions based on trends. When performances were graphed, changes were seen to occur in steps (a sharp change), as small gradual changes, or both together in varying frequencies of occurrence. If the pattern of record performances changes frequently, in both gradual and step forms, the event exhibits an unstable history which results in poor predictions of future performances.

The swimming events appeared to be in two groups (see Appendix C). The sprints were displayed mainly by step form, and the distance events showed a more gradual decline. Athletic events on the other hand appeared to demonstrate more gradual changes, with the exception of the men's 100 and 400 metres.

Wild predictions. When predictions were scrutinized for their absolute values, inconsistencies were seen. For example, by 1984 the predicted record for the Women's 800 metre Free-style would be faster than the men's time for that event. In the Women's 1,500 metre Free-style, the predicted record indicated a pace faster than the world record for the 400 metre Free-style. The Women's 4 x 100 metre Free-style Relay indicated a time that was almost 10 seconds faster than four times the 100 metre world record. In events where these 'wild predictions' occurred the most plausible interpretation that can be offered is that their history of development has been highly inconsistent and rapid.

Personalities. In the past there have been individuals who produced outstanding performances. Their records have produced in their respective events a plateau for a number of years. The impact of these enduring performance records affects prediction. The anomaly in the curve of development produces an inconsistency which cannot be handled adequately in a statistical fashion. Some personalities who produced performances which endured for a relatively long period of time were Don Schollander (1960's - 200 metre Free-style), Roland Matthes (1970's - 100 and 200 metre Back-stroke), Catie Ball (1960's - 70's - 200 metre

Breast-stroke) and Mark Spitz (1970's - 100 and 200 metre Butterfly).

Developments in technique and training. The free-style swimming action has evolved over a long period of time. It could be interpreted that its evolution would be a great deal more advanced than one of the 'newer' swimming strokes such as butterfly. If this was the case, then the varability in event record development could be attributed partly to changes in technique. This is also possible with changes in training methods. The introduction of weight training, interval training, and vast increases in the quality and quantity of training work could have influences on performances which cause sudden changes in the pattern of record development.

The factors which are indicated above are only some of the more obvious confounding influences which affect the pattern of record development. It is obvious that world records reflect many influential factors. For the prediction of most athletic and swimming events to be adequate it would be a better strategy to attempt to take into account all significant influences on performance. Thus, the development of a polynomial multiple regression equation would seem more appropriate. Prediction from world record performances alone, appears to be a relatively futile procedure for most athletic and swimming events.

CHAPTER V
CONCLUSION

This thesis showed that world record performances alone were not good predictors. They did not reflect the influences of individual personalities, technique, training and equipment developments, rule changes, etc. Unless there were consistant patterns of record changes adequate predictions were not possible.

For statistical analysis the data used were too variable for prediction purposes. Some events seemed to produce reasonable predictions but the majority of the events considered were problematical. The large amounts of error on most predictions indicated the inconsistencies in the developmental patterns of world records.

As a general procedure, this research strategy was found to be inadequate because of the nature of the historical data. Future researchers will have to be more selective in the forms of data that are used.

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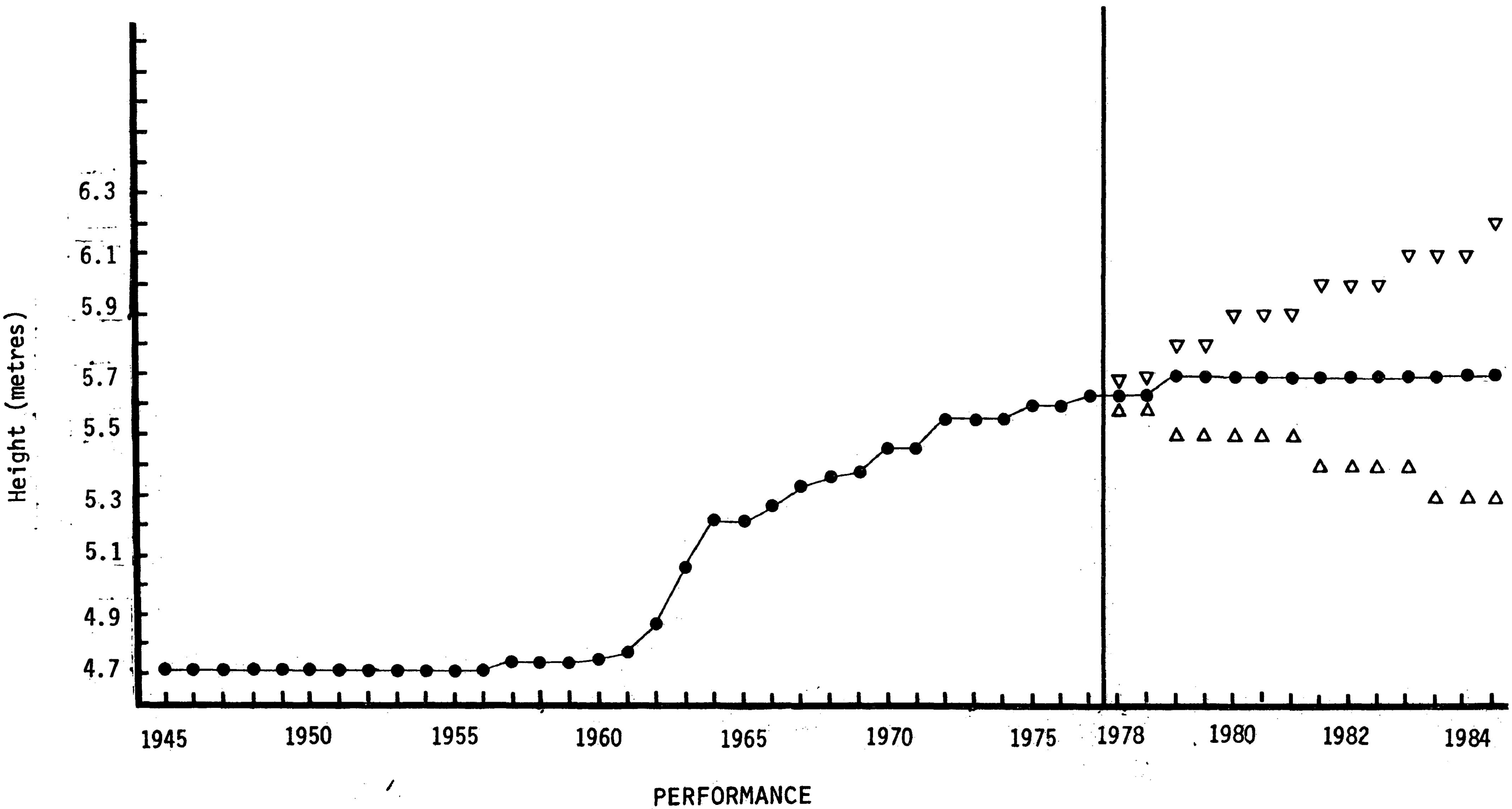
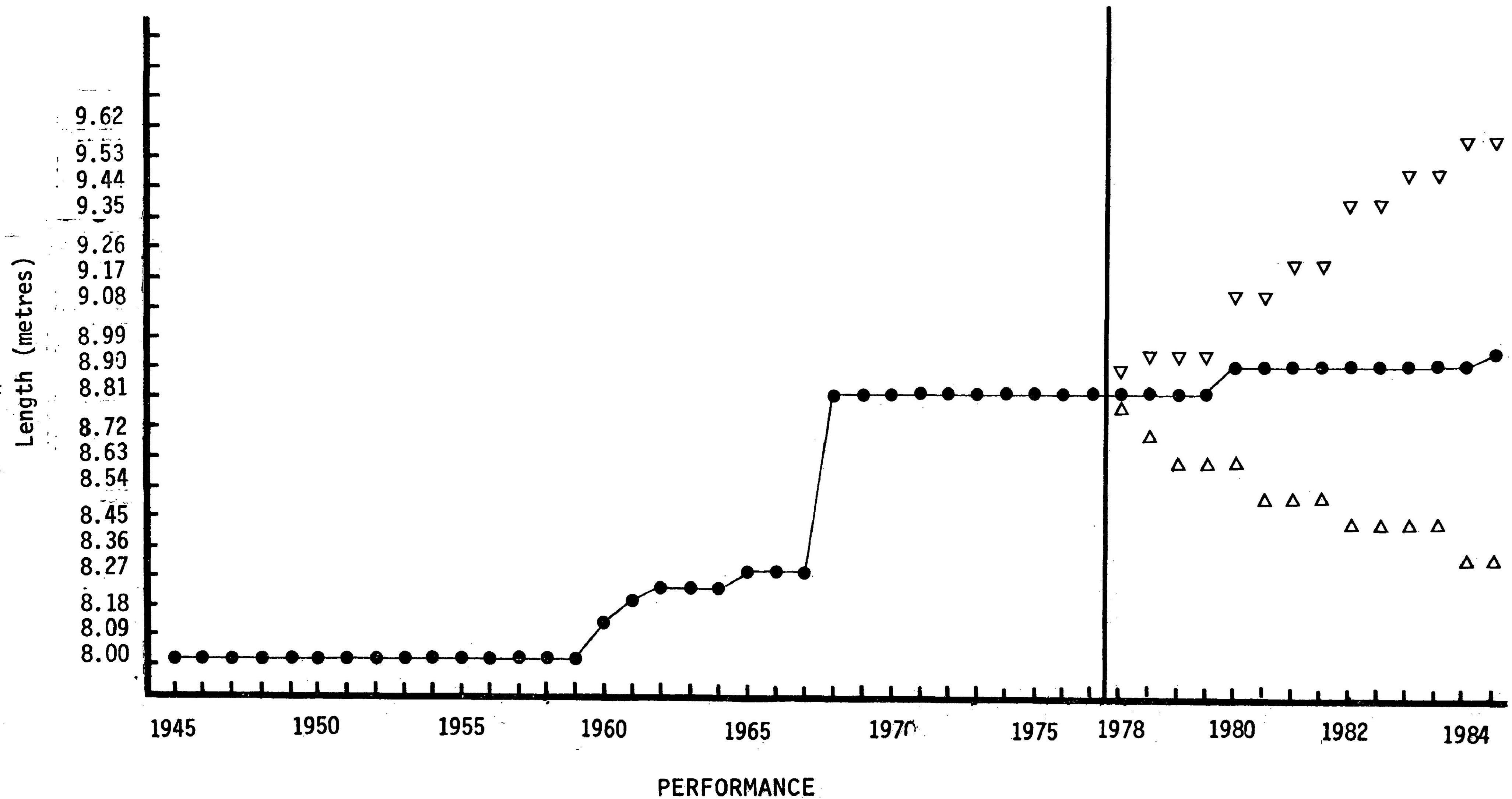
APPENDICES

Appendix A

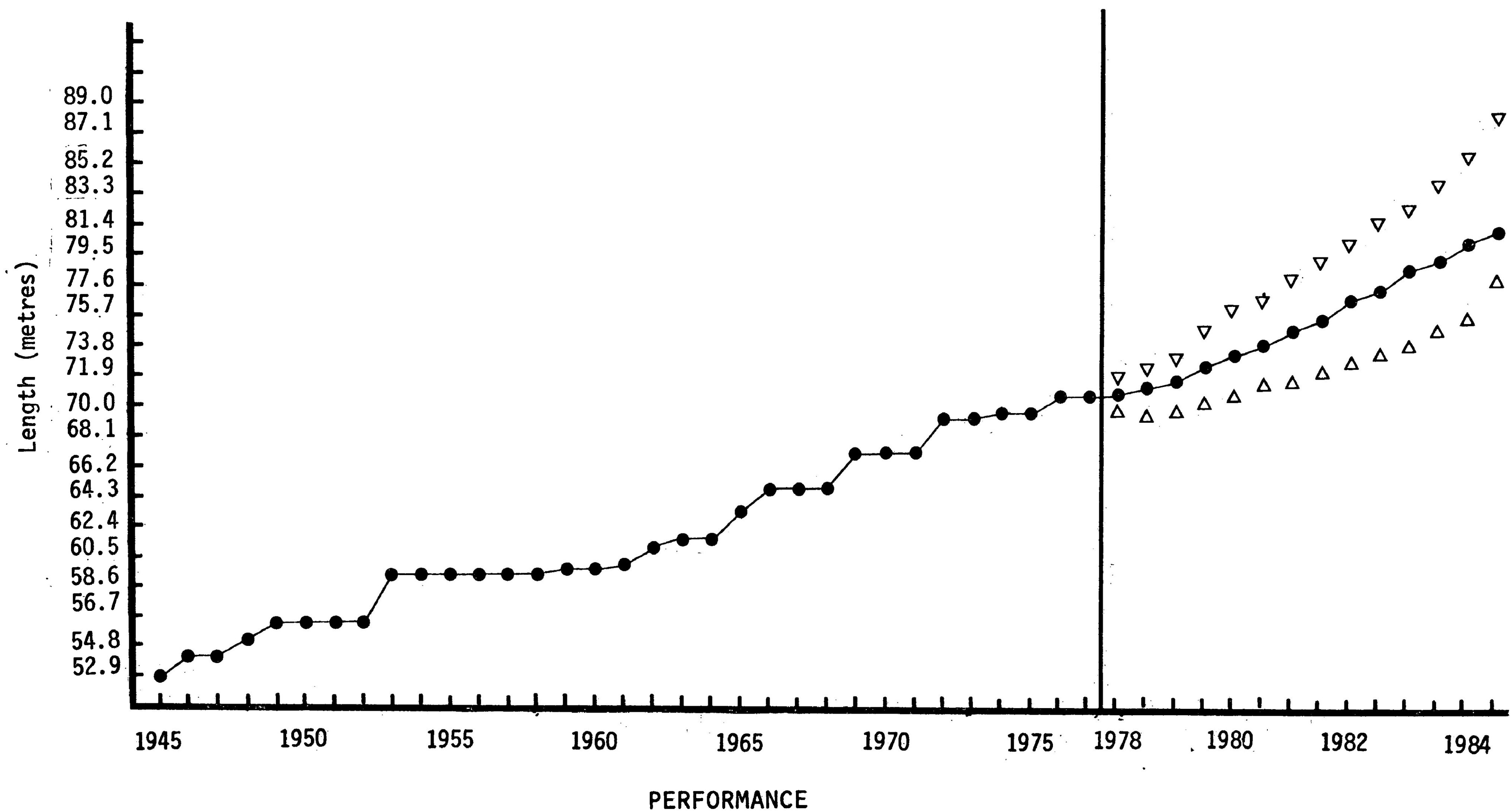
Graphs for field events



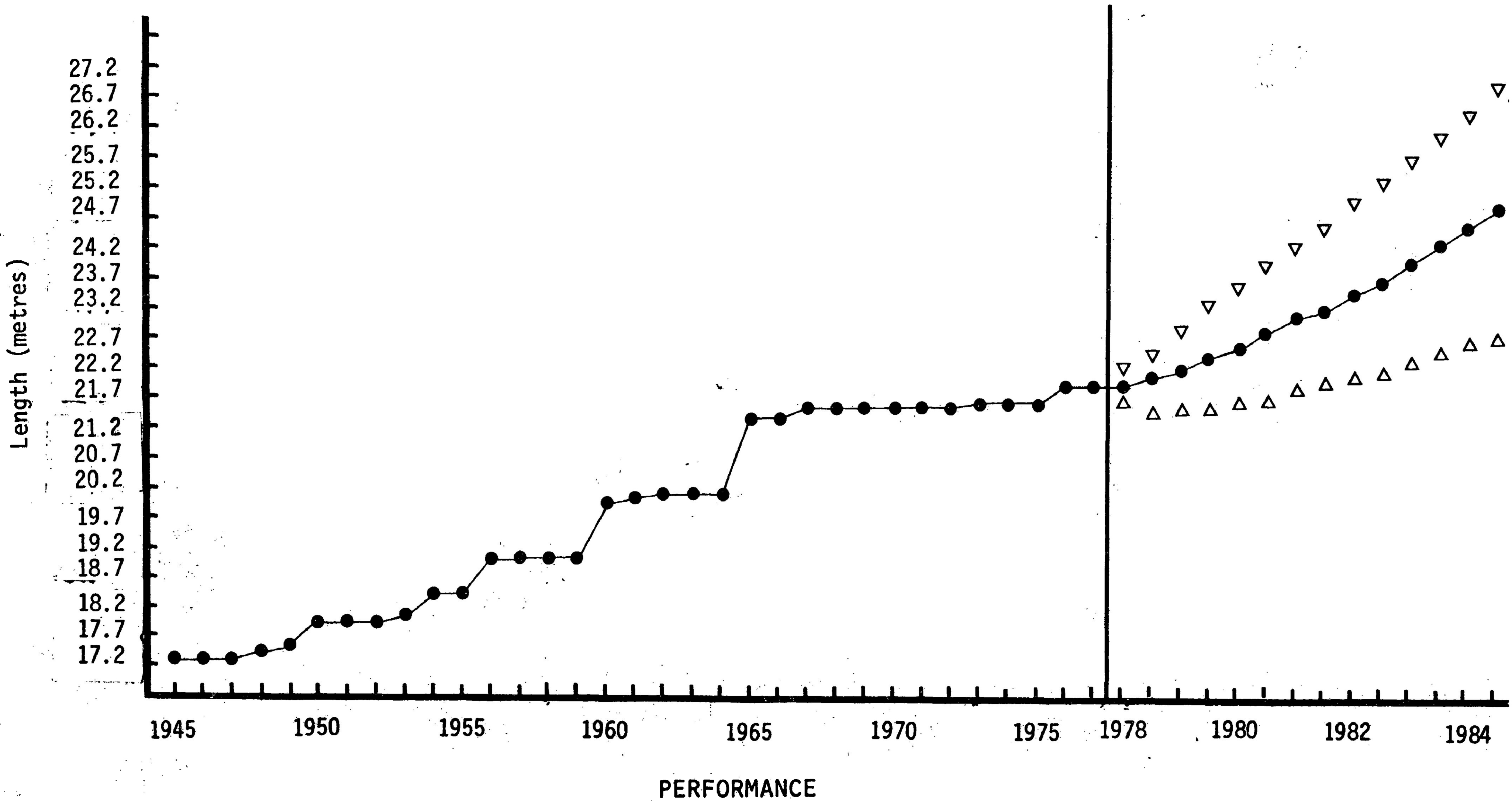
Men's Pole Vault



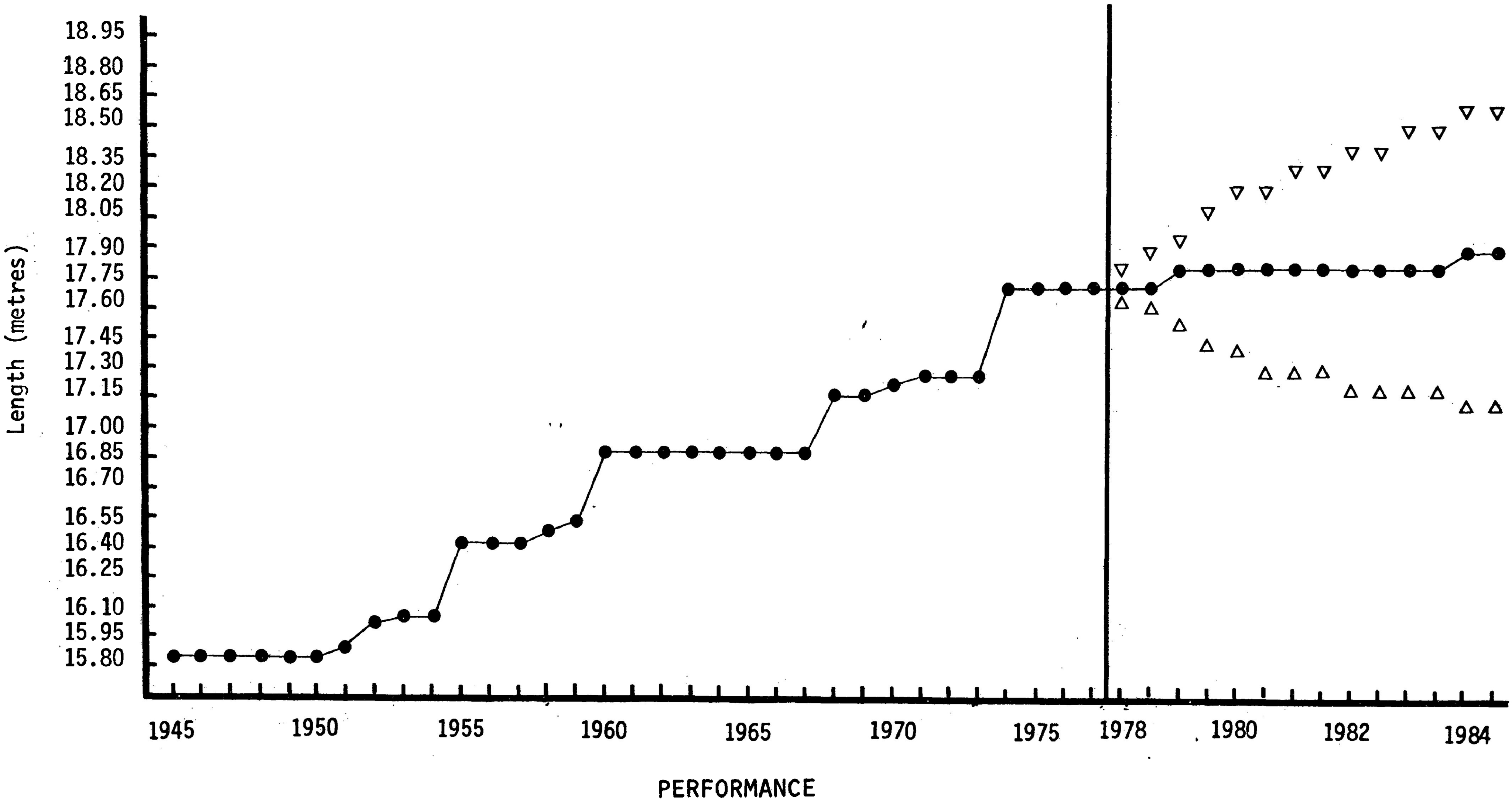
Men's Long Jump


Length (metres)
89.0
87.1
85.2
83.3
81.4
79.5
77.6
75.7
73.8
71.9
70.0
68.1
66.2
64.3
62.4
60.5
58.6
56.7
54.8
52.9
1945
1950
1955
1960
1965
1970
1975
1978
1980
1982
1984
PERFORMANCE

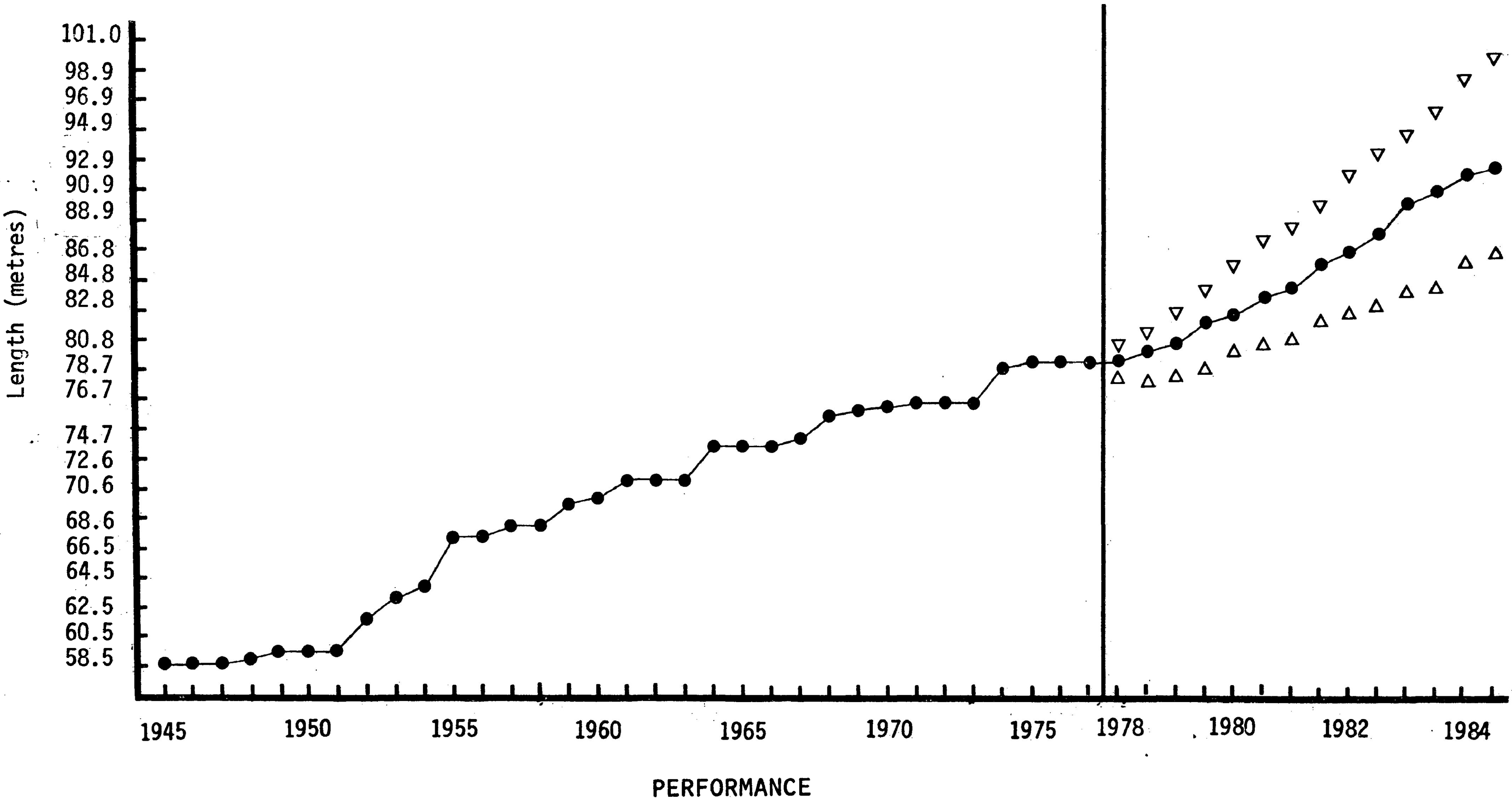
Men's Discus



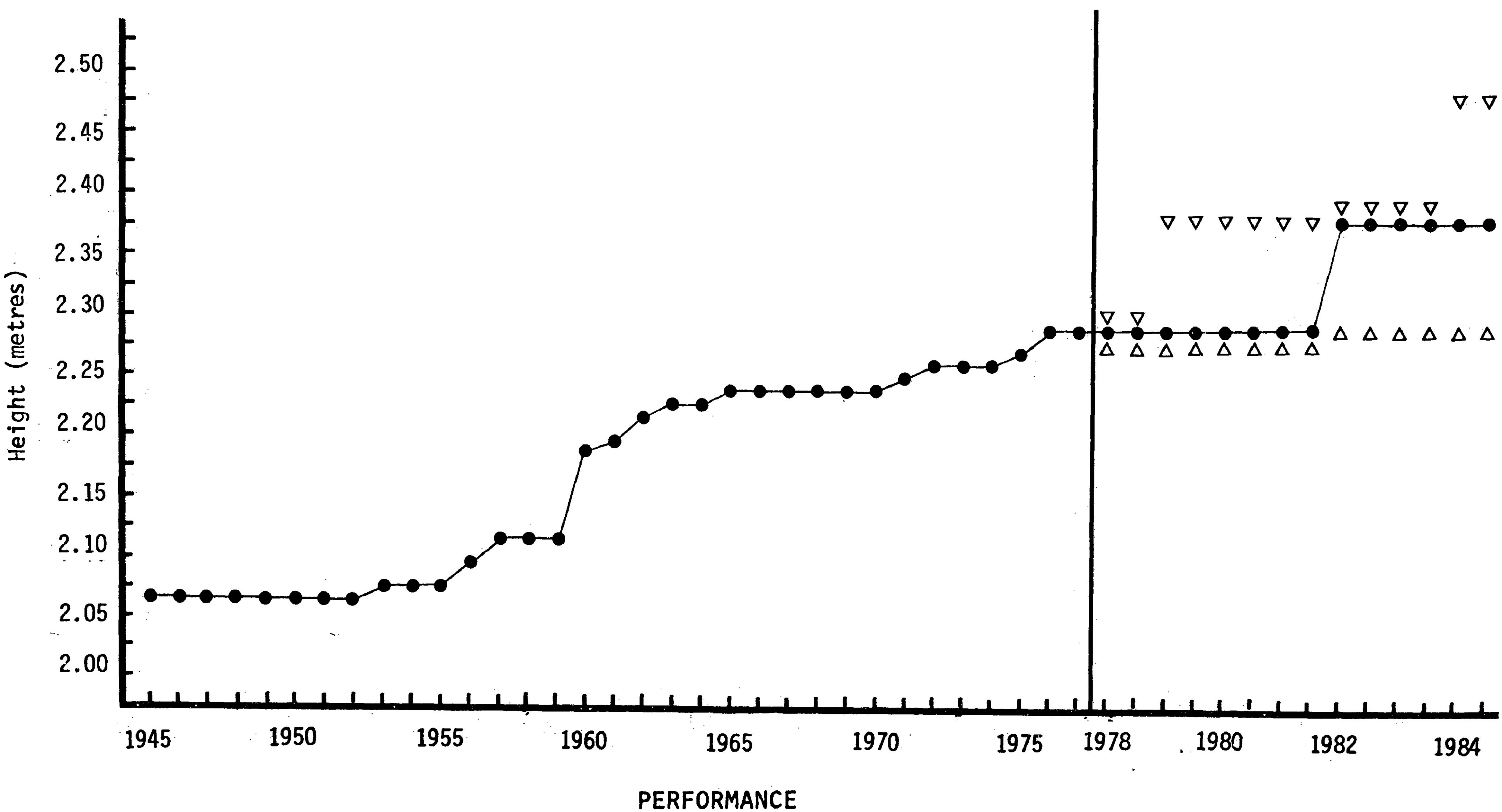
Men's Shot Put



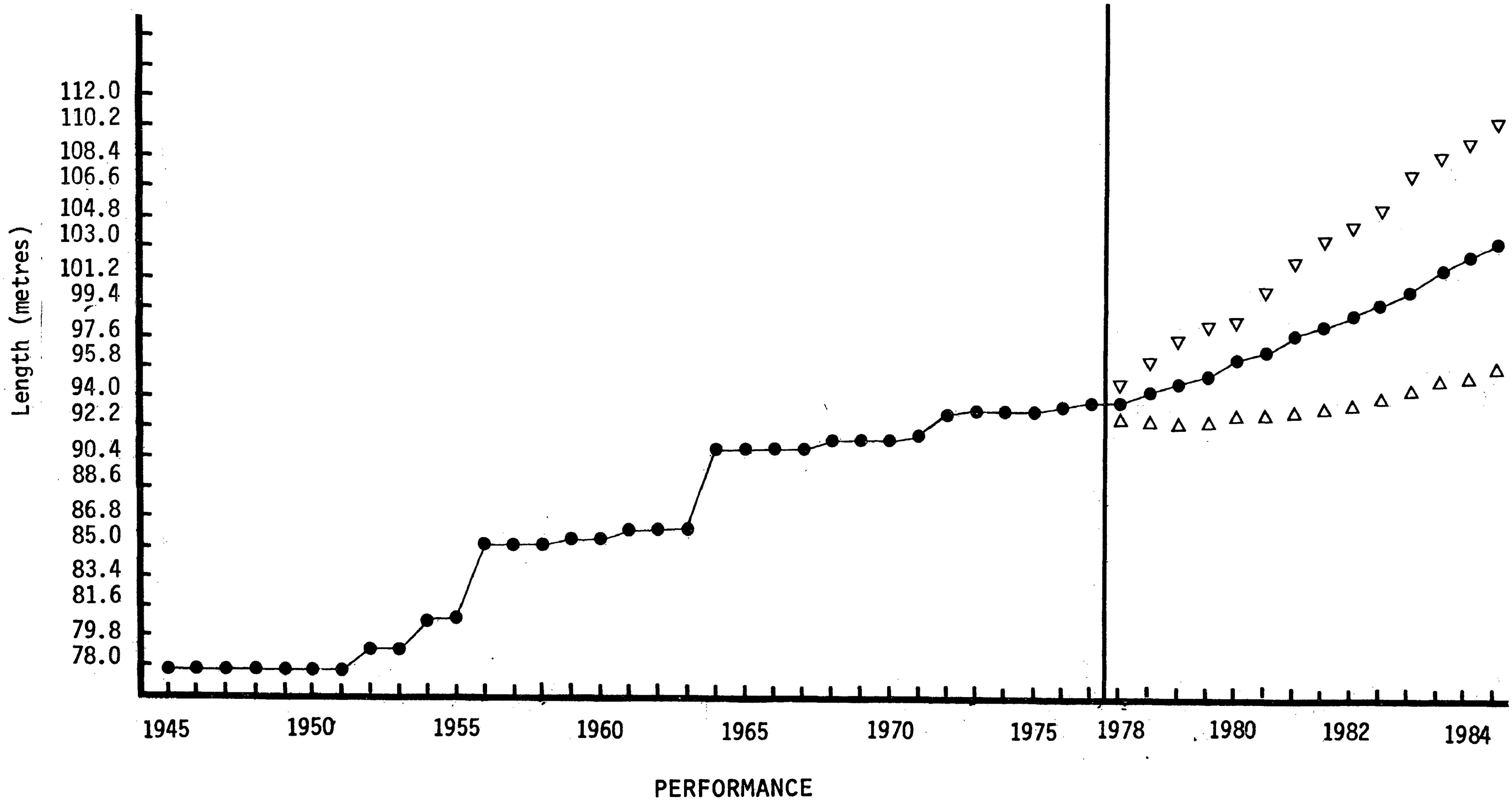
Men's Triple Jump



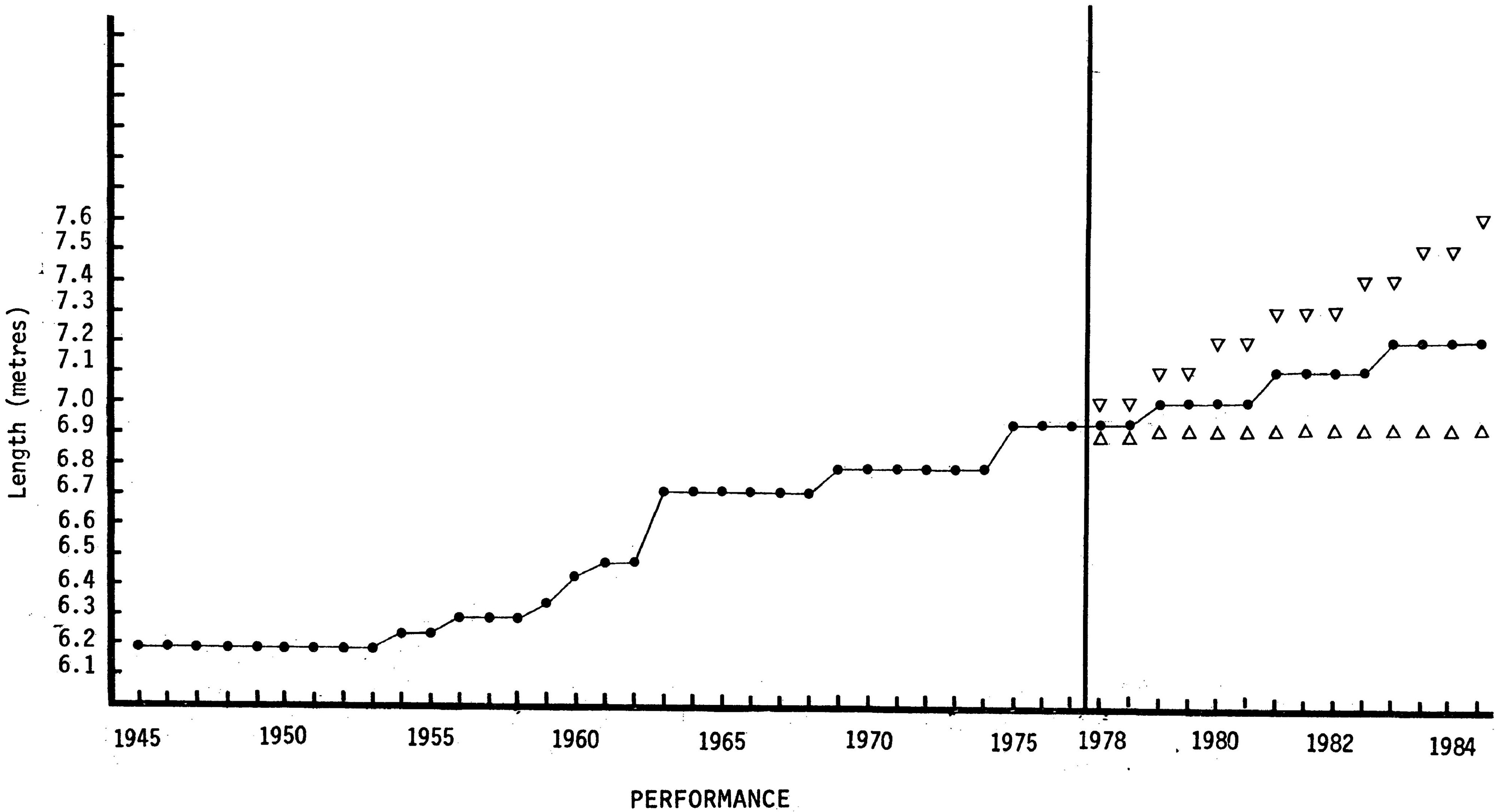
Men's Hammer Throw



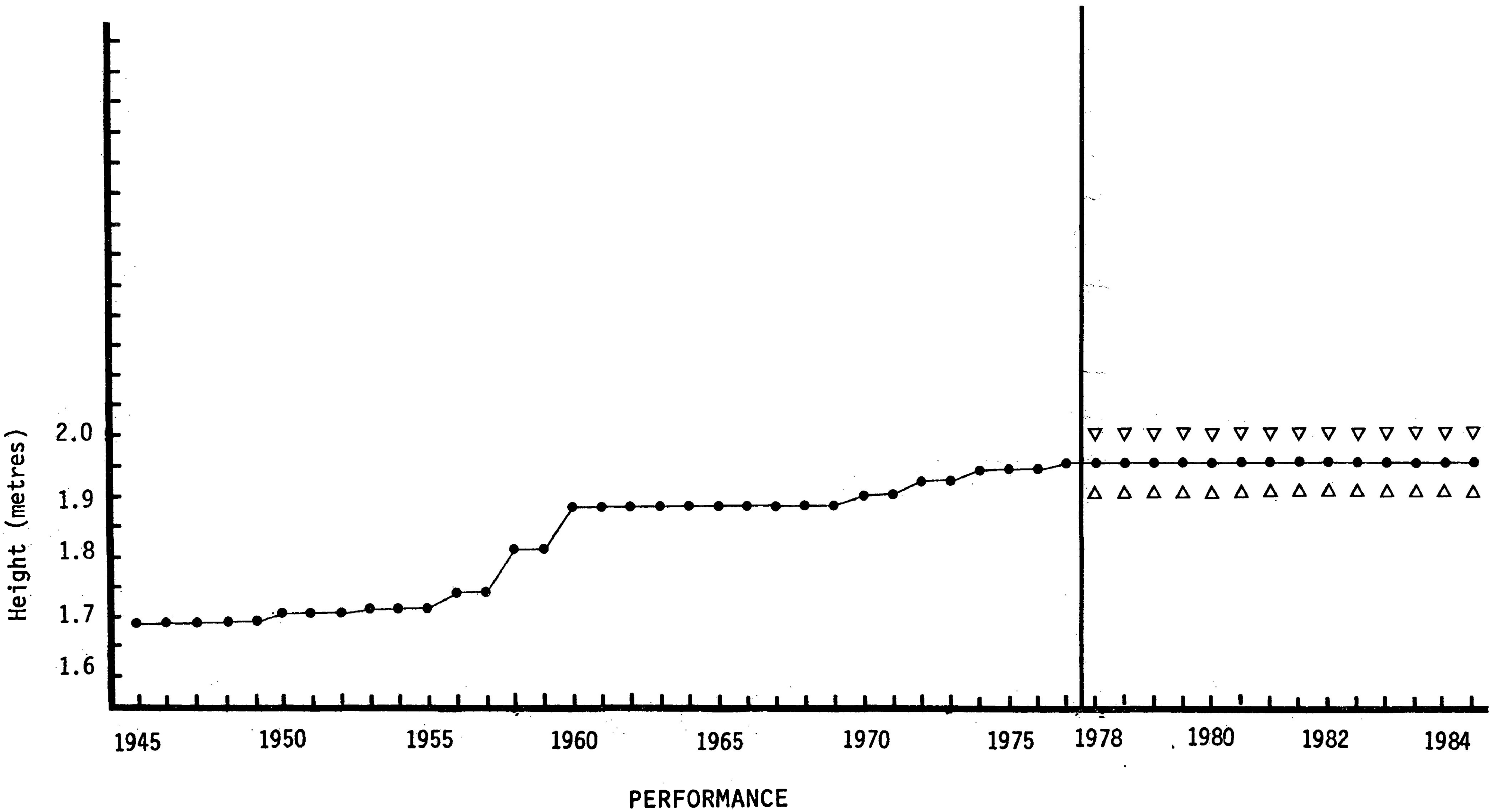
Men's High Jump



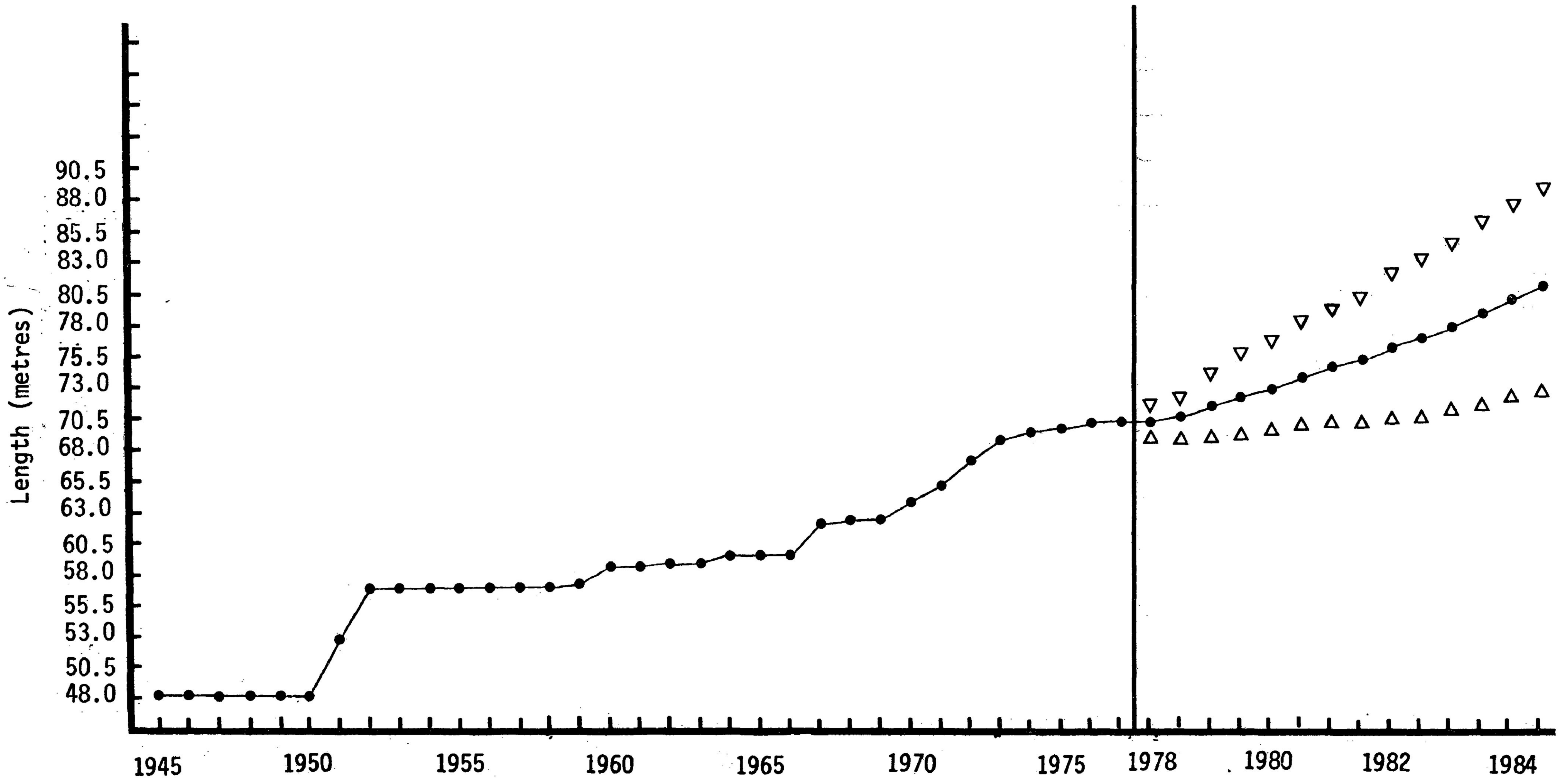
Men's Javelin



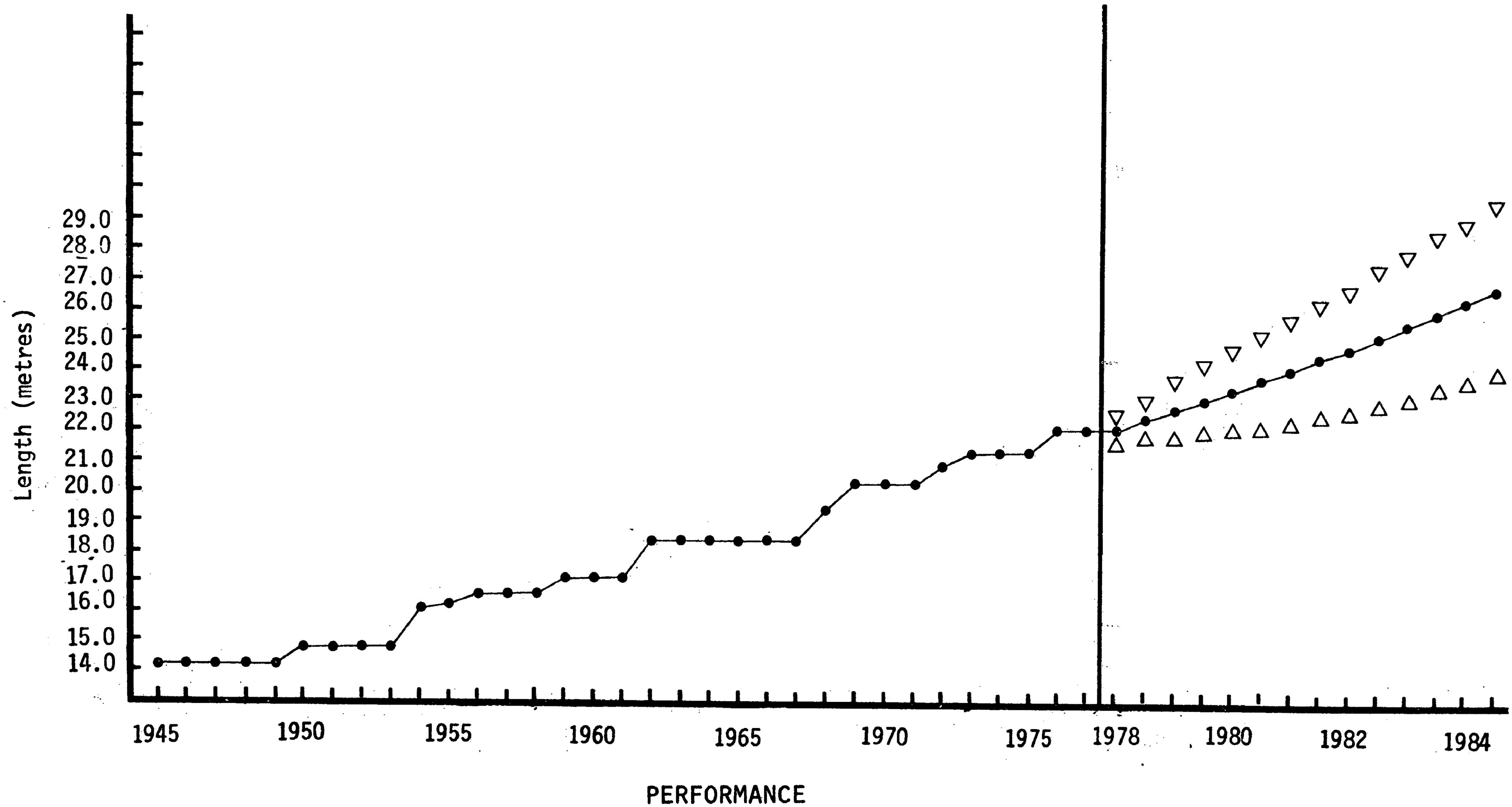
Women's Long Jump



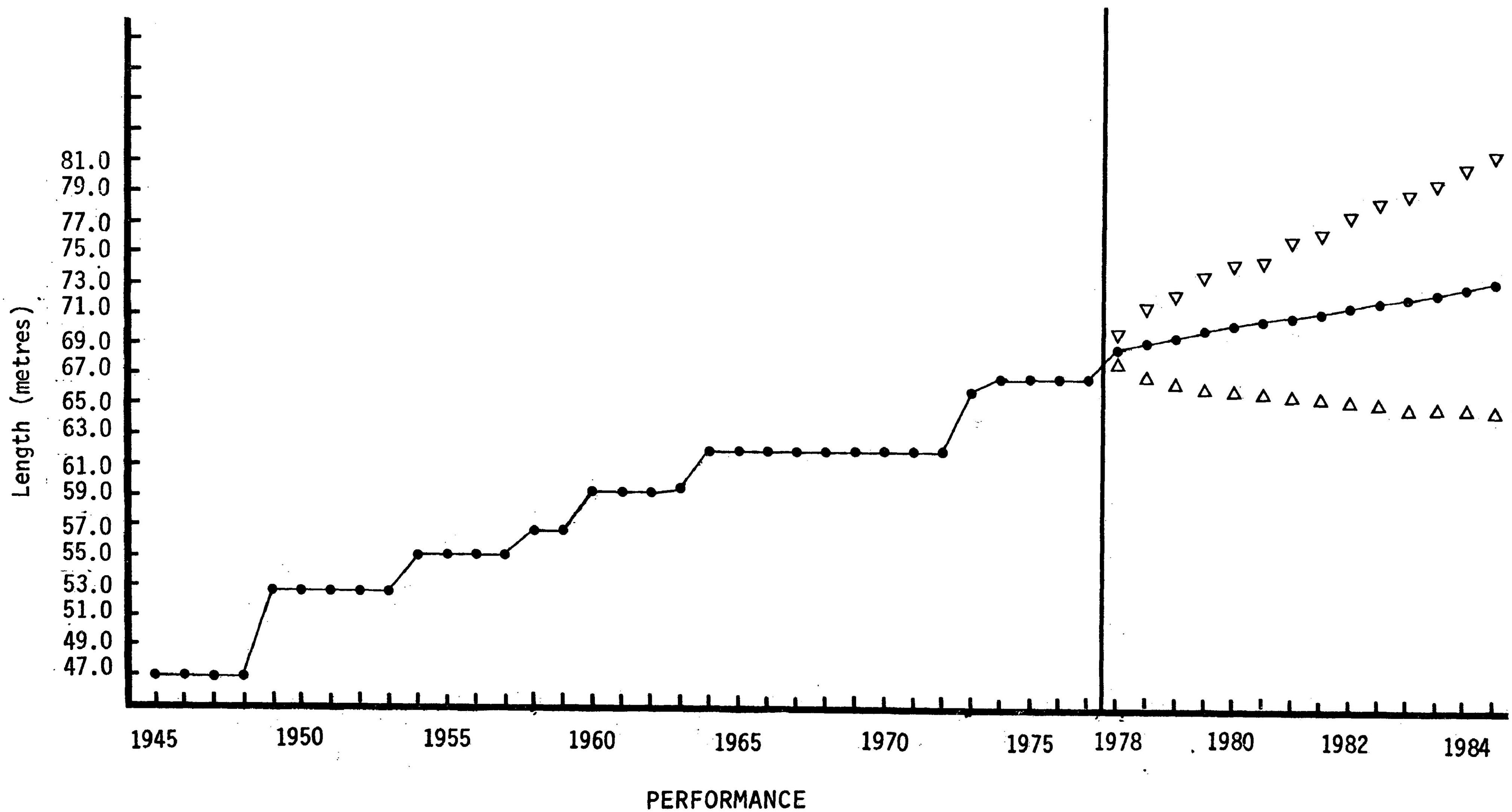
Women's High Jump



Women's Discus



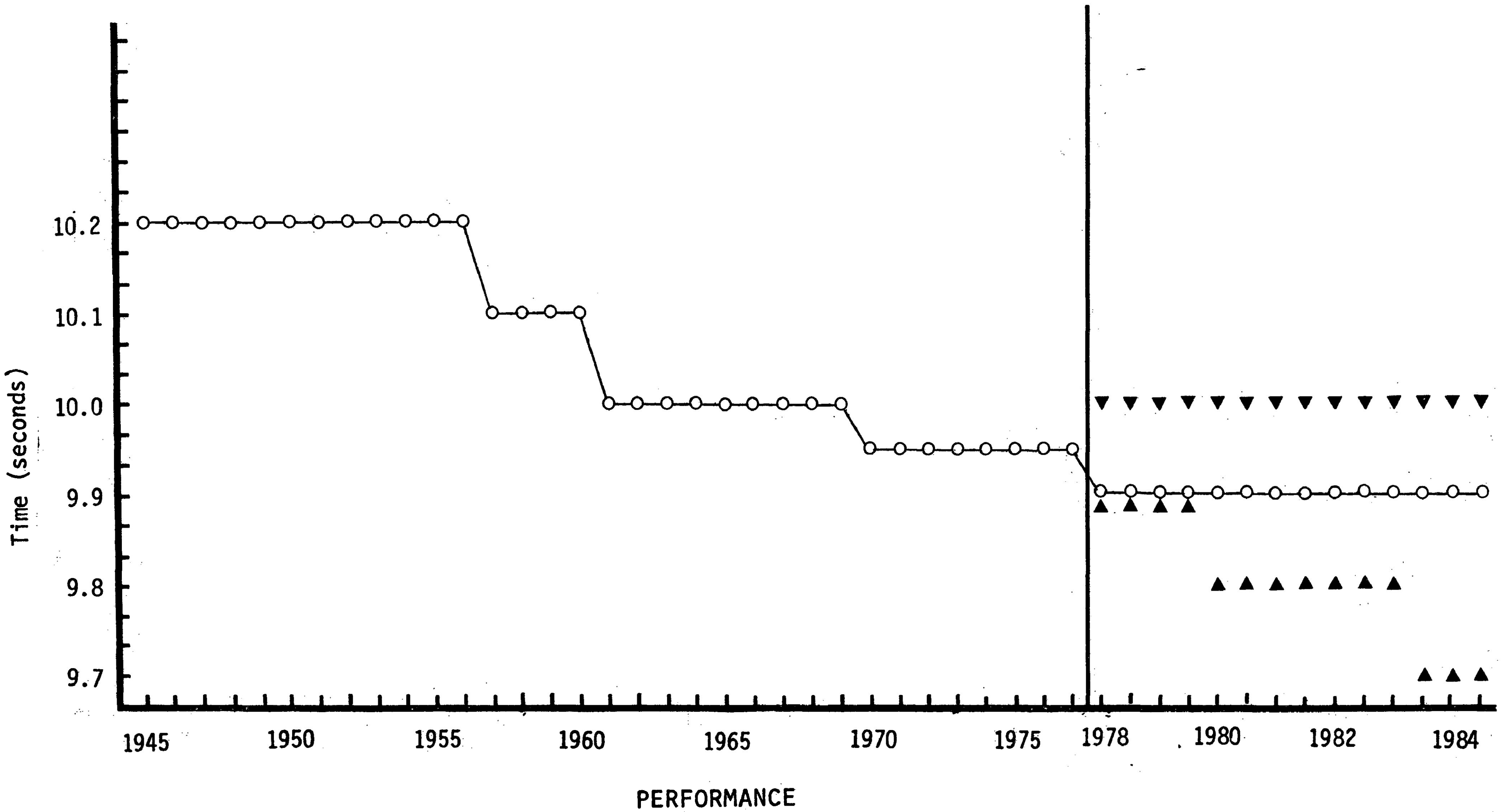
Women's Shot Put



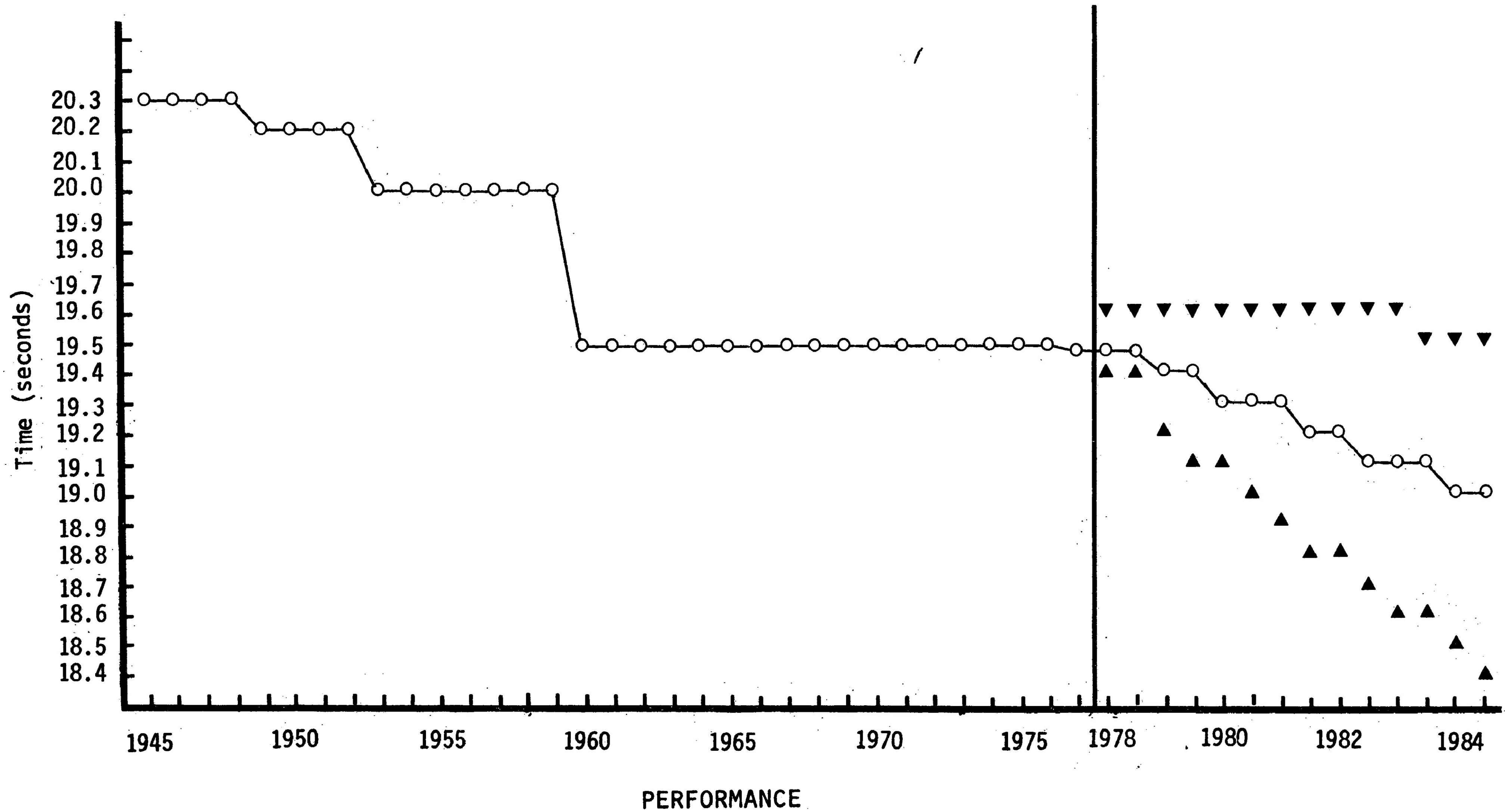
Women's Javelin

Appendix B

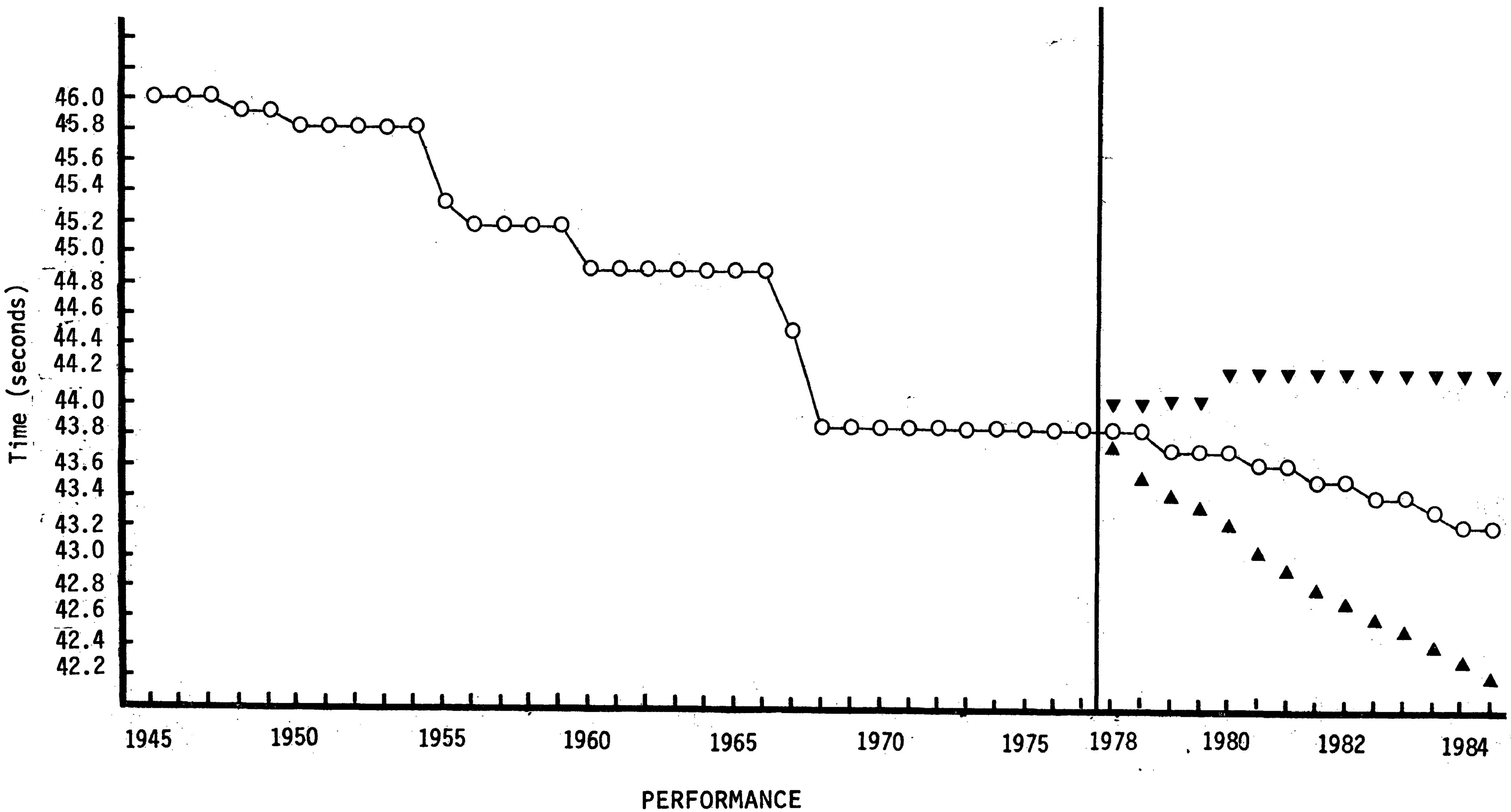
Graphs for track events



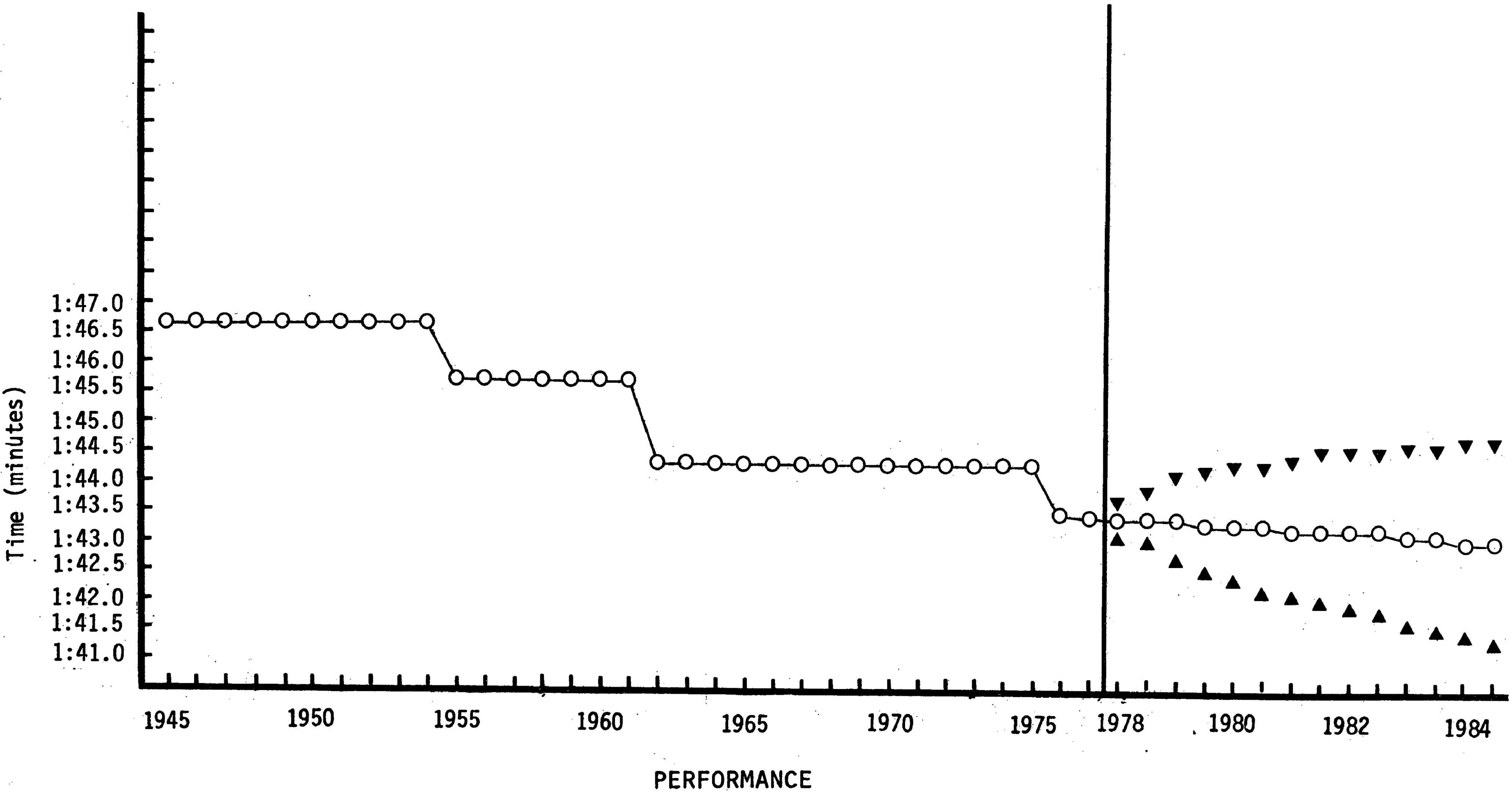
Men's 100 Metre Dash



Men's 200 Metre Dash

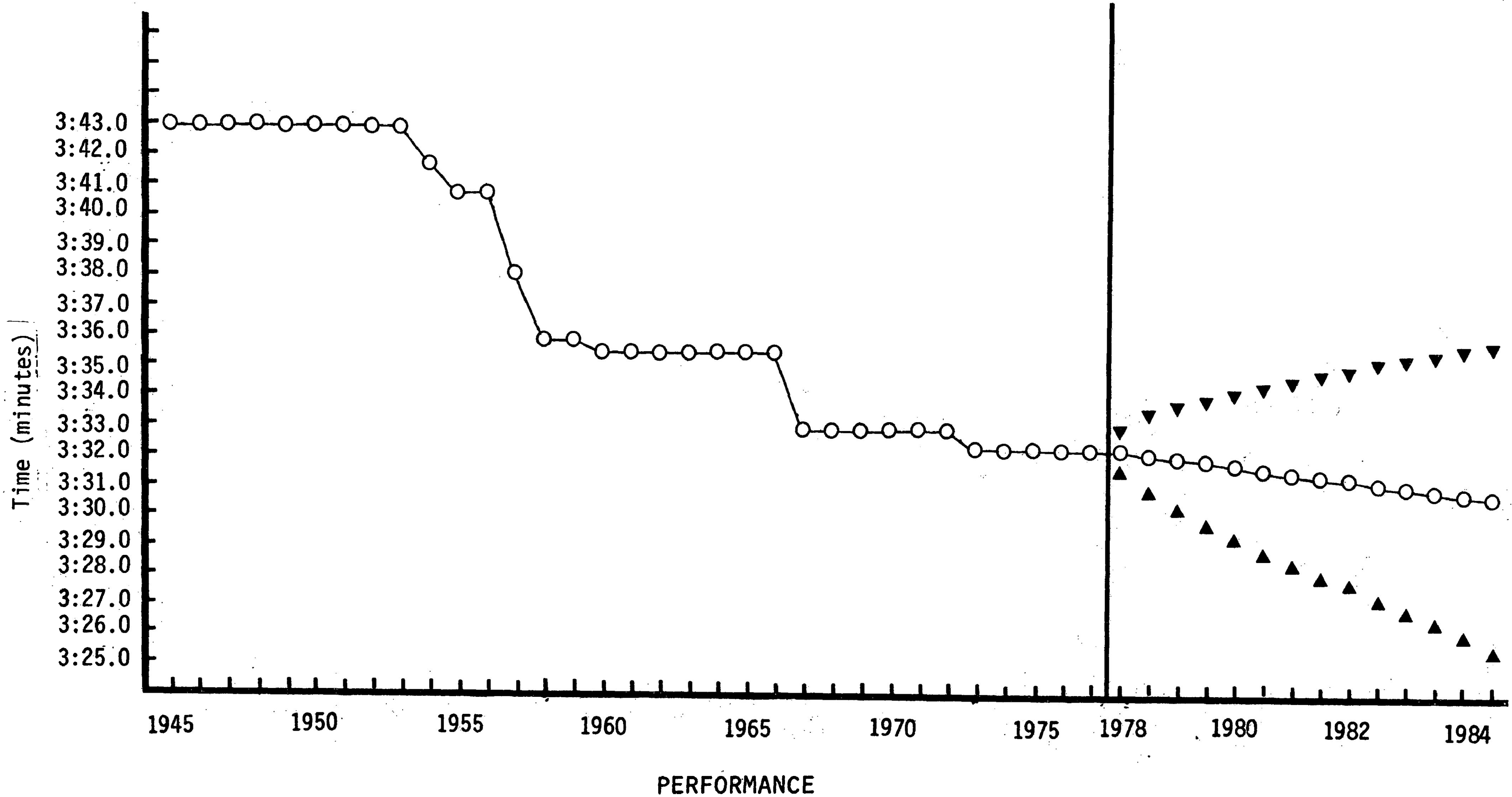


Men's 400 Metre Dash

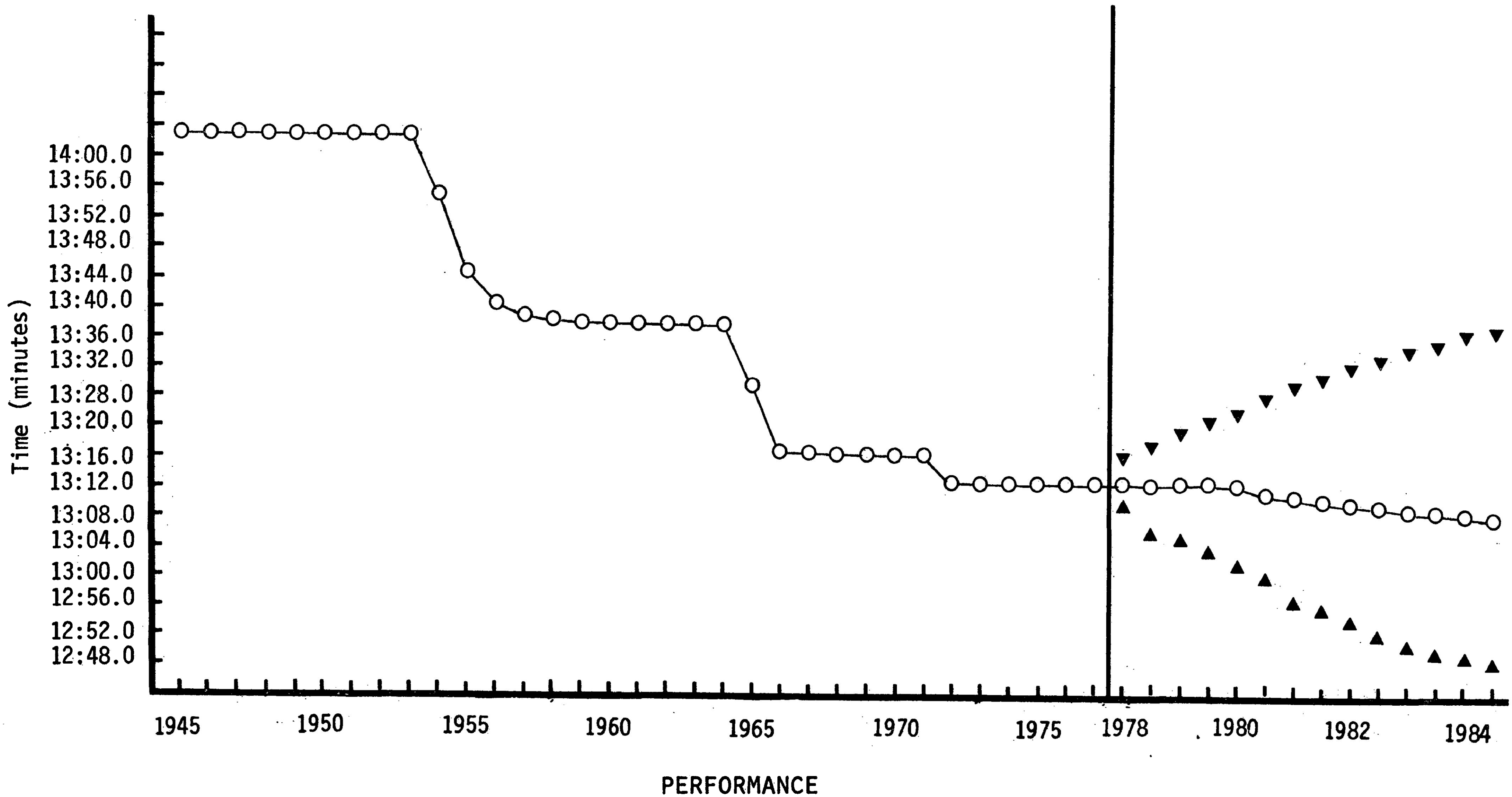


Men's 800 Metre Run

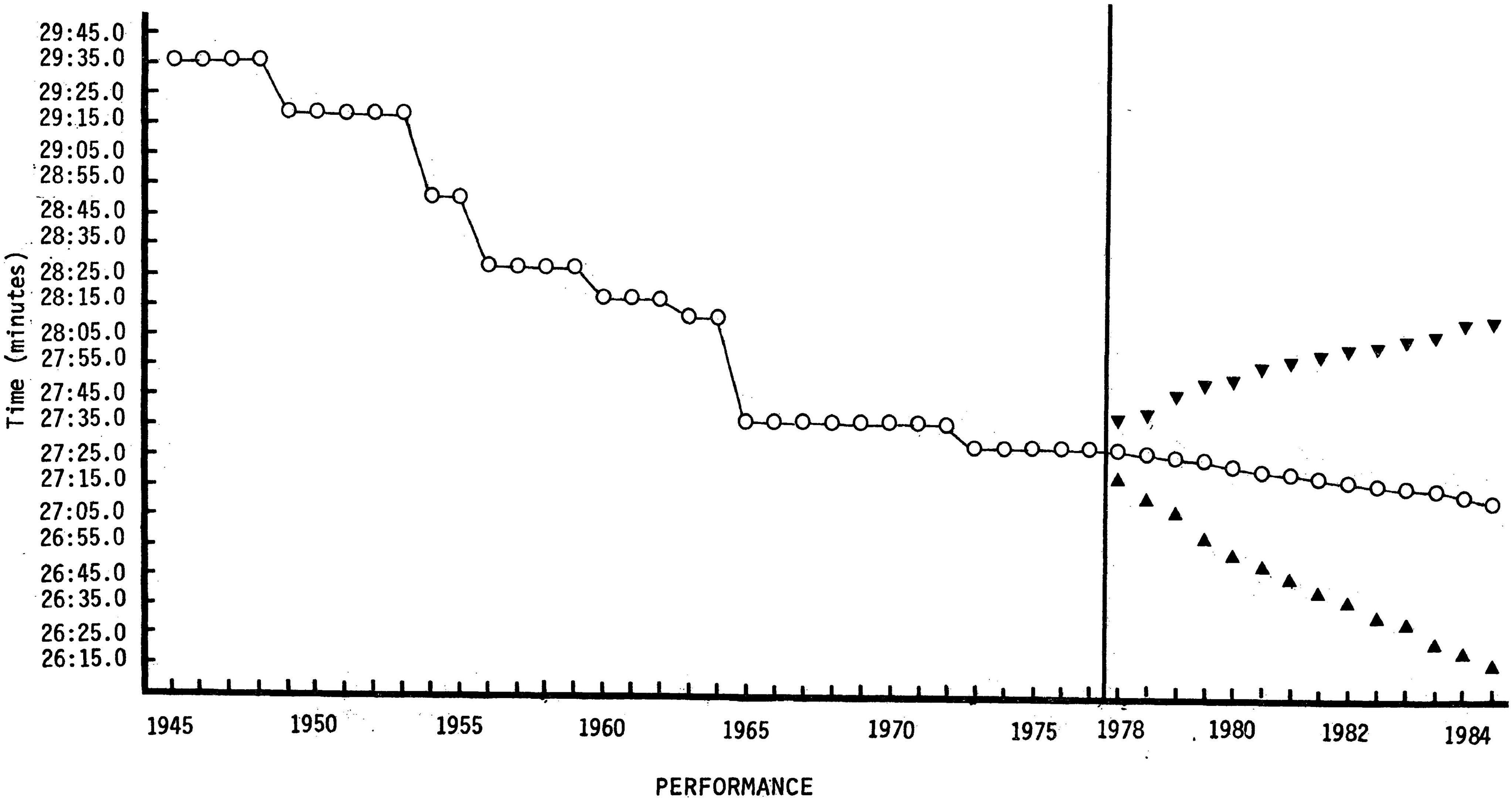
55



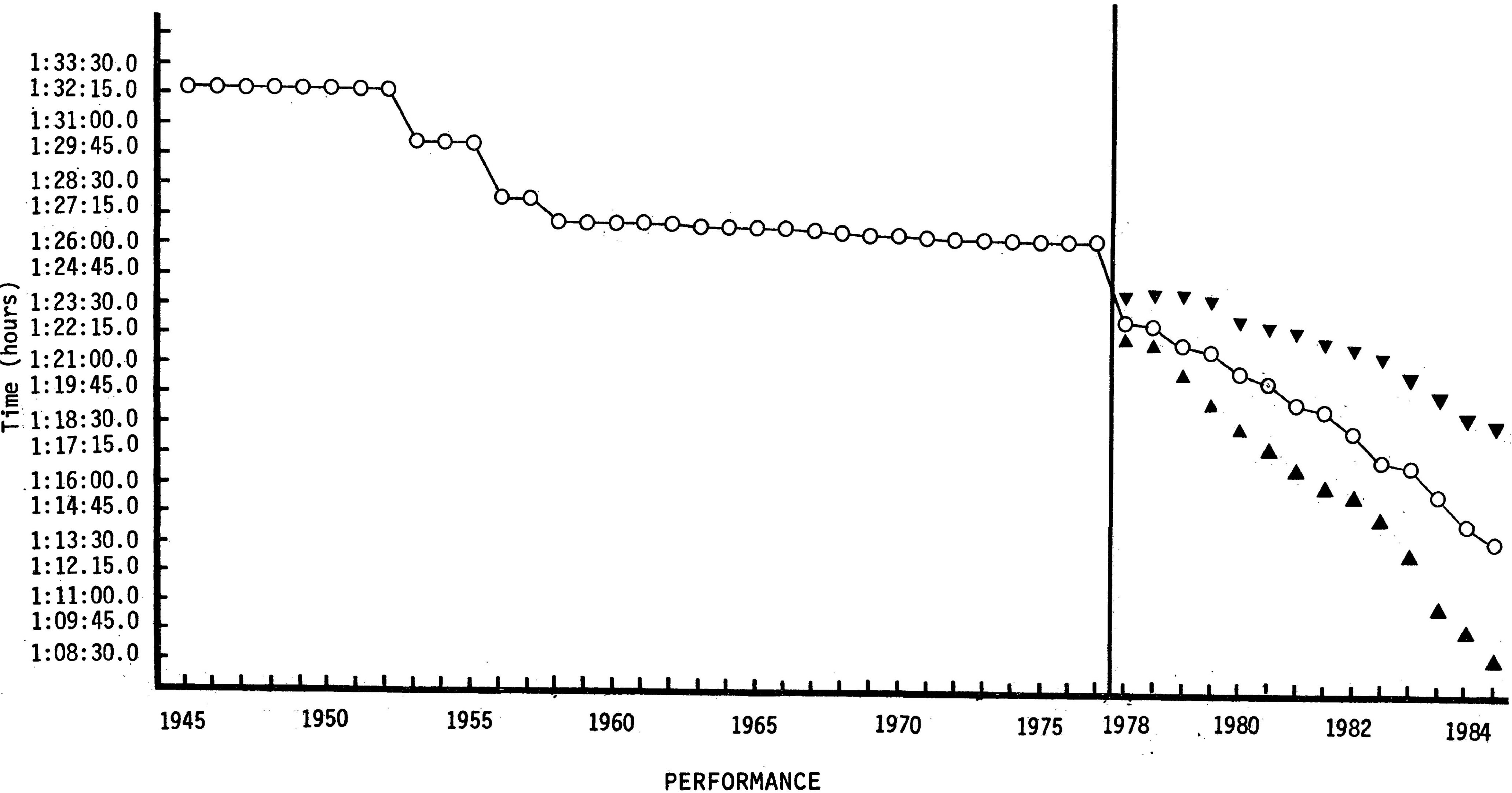
Men's 1,500 Metre Run



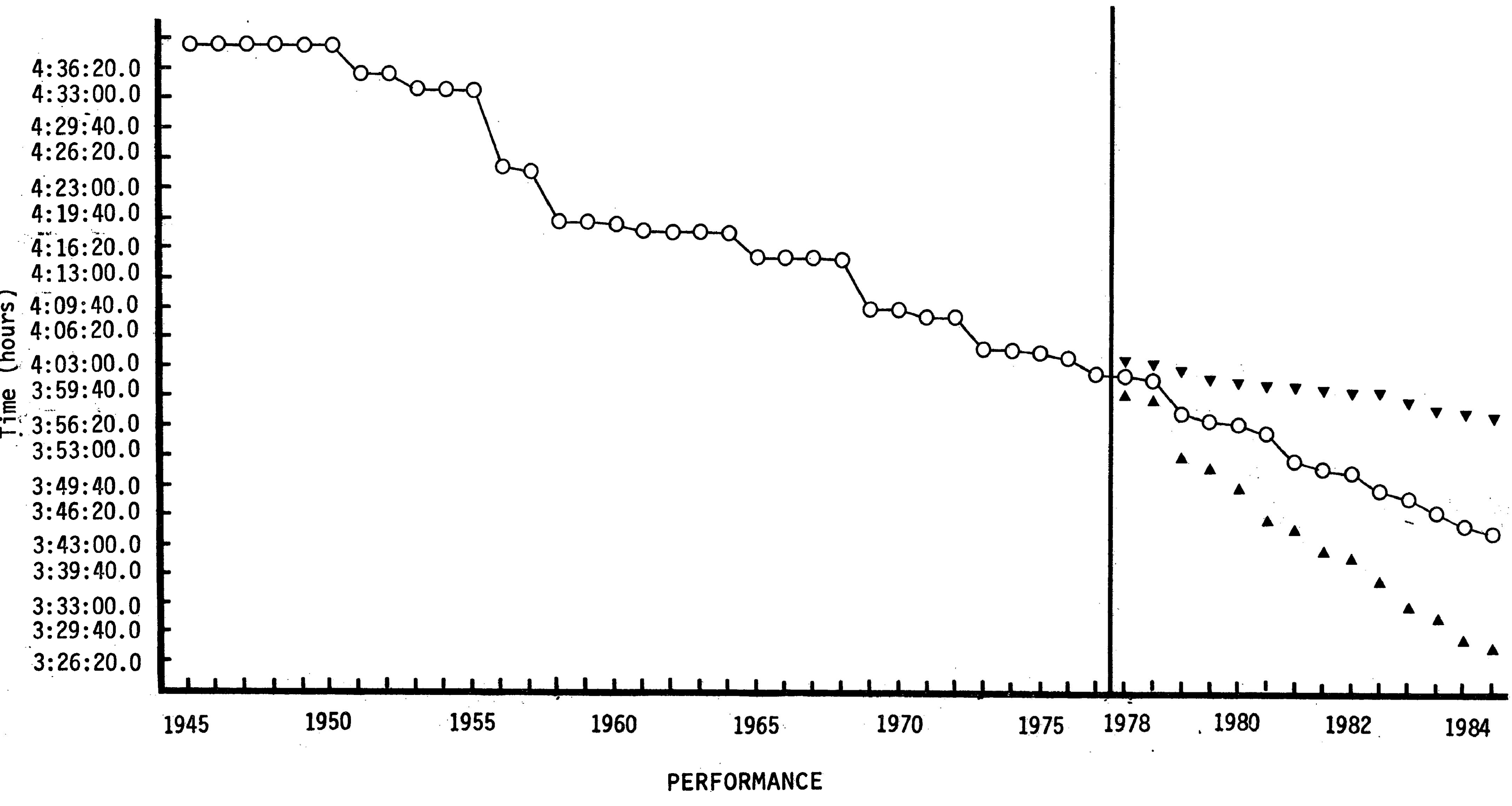
Men's 5,000 Metre Run



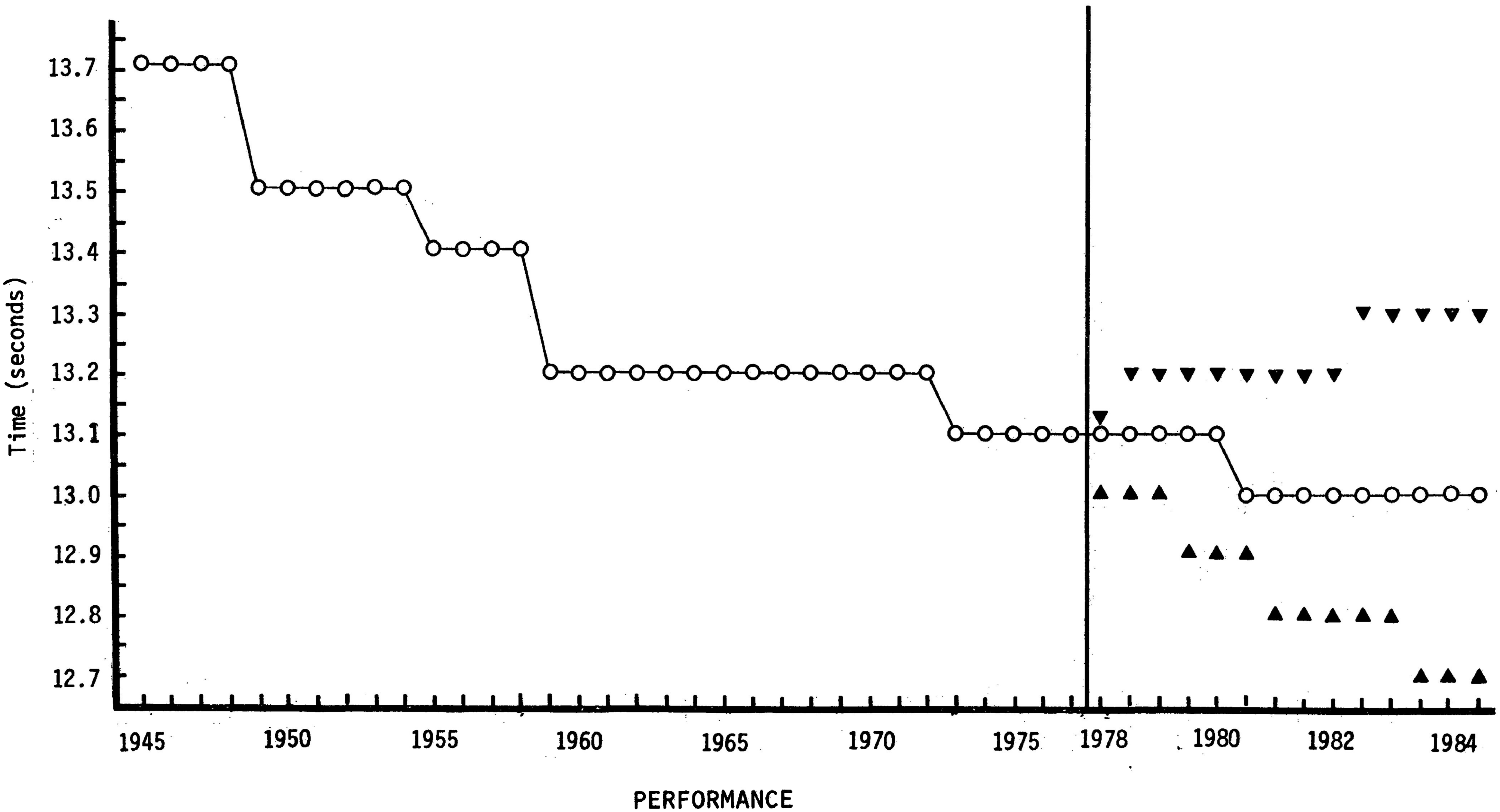
Men's 10,000 Metre Run



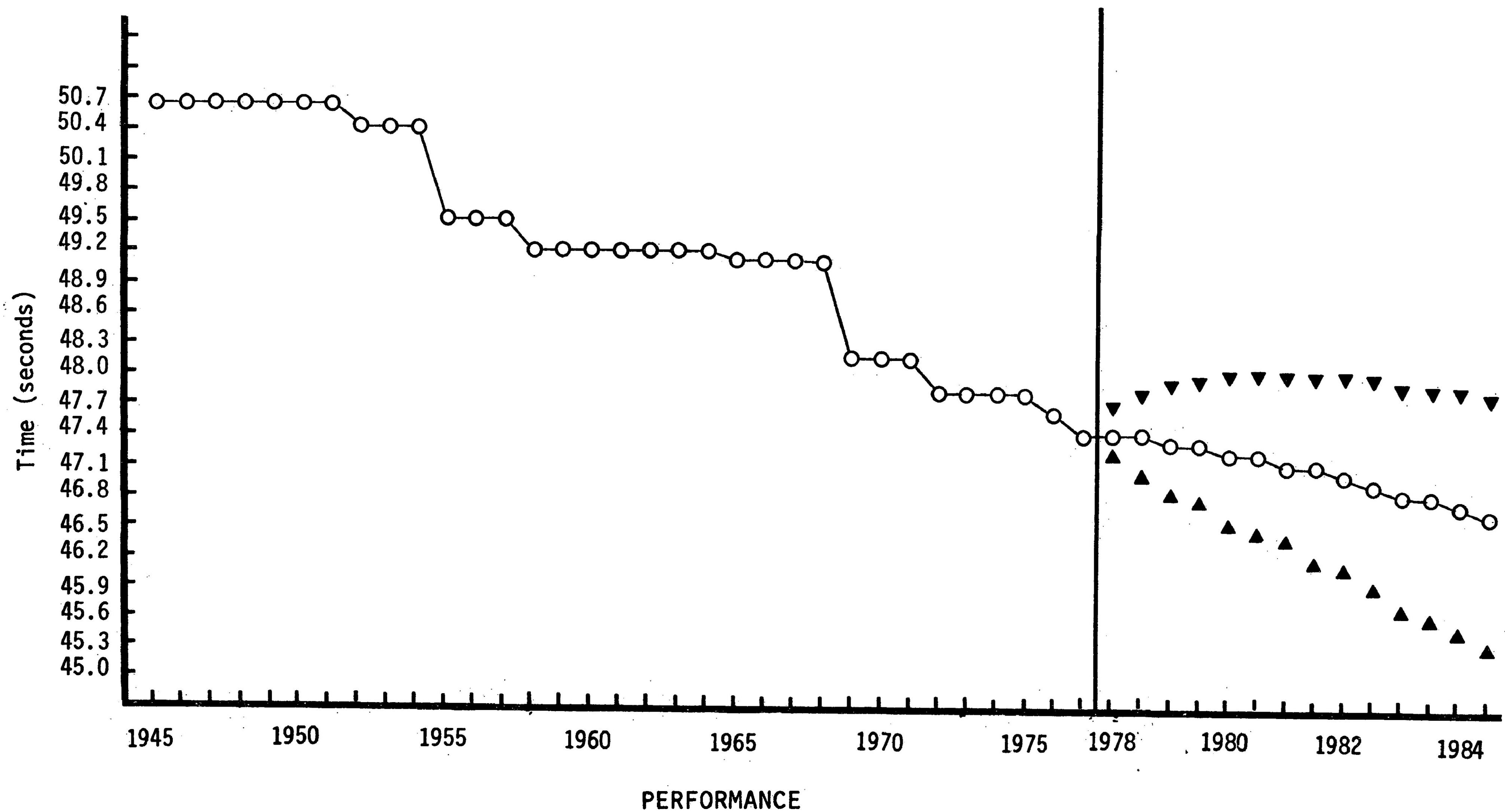
Men's 20,000 Metre Walk



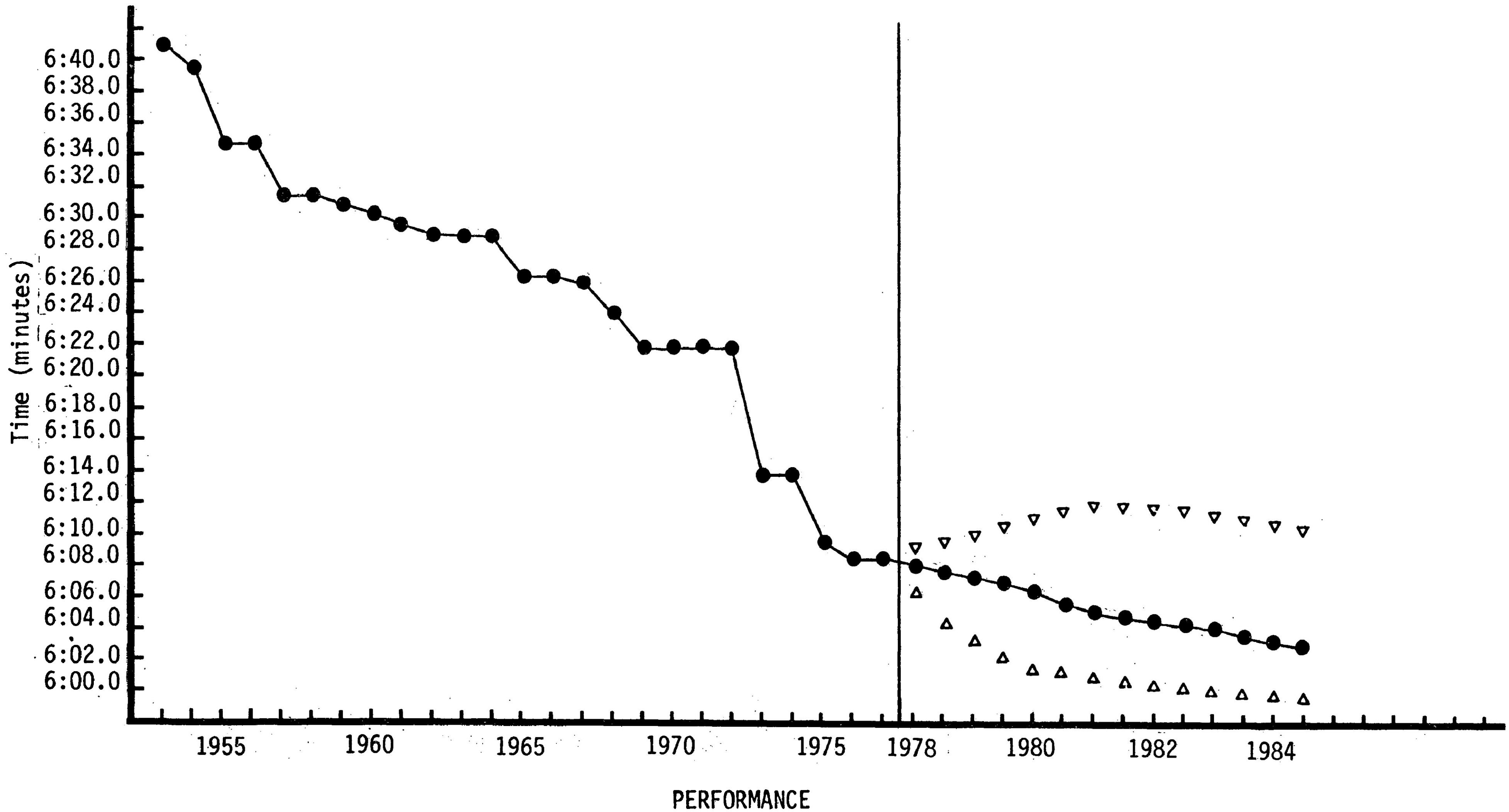
Men's 50,000 Metre Walk



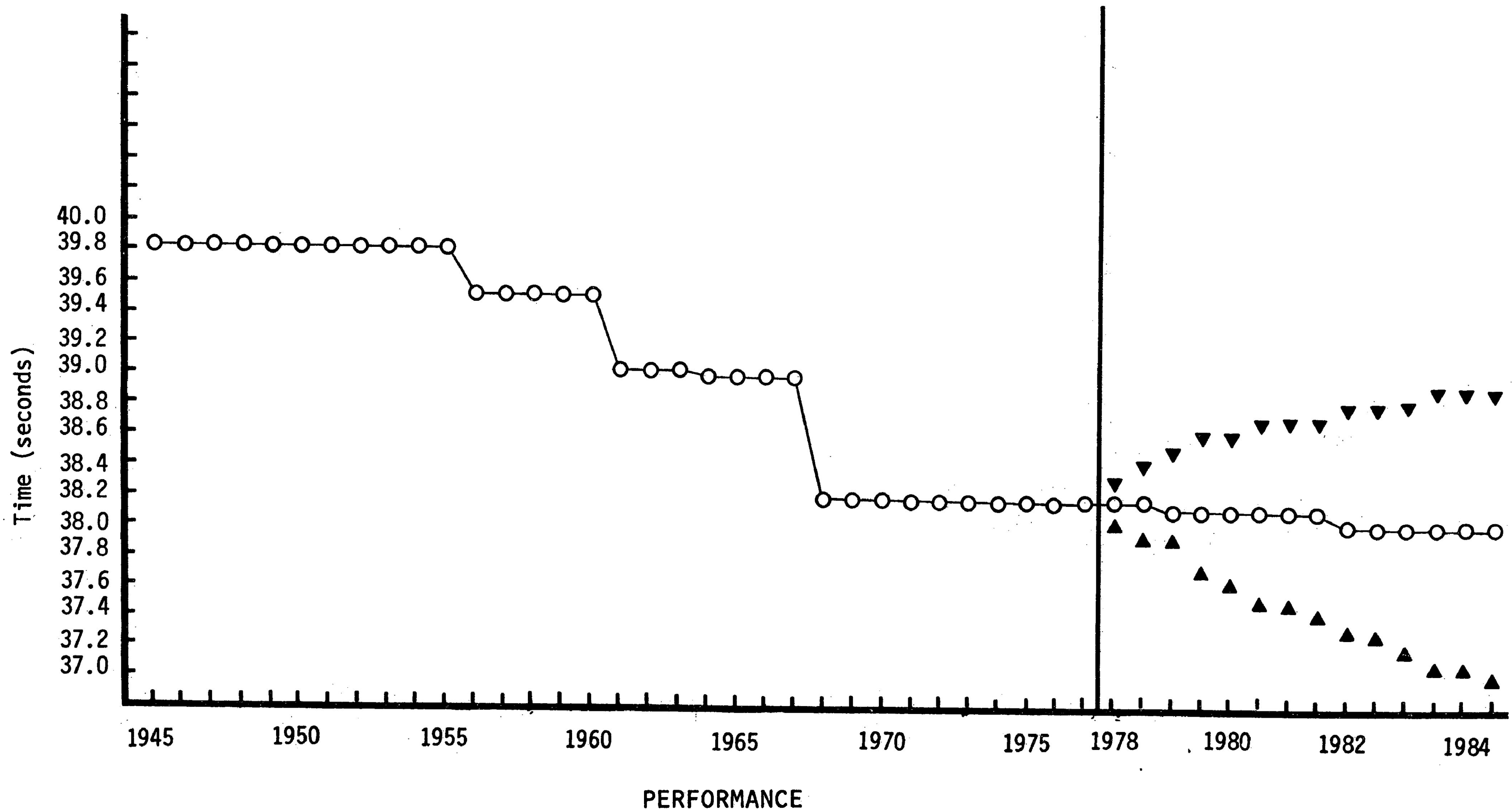
Men's 110 Metre Hurdles



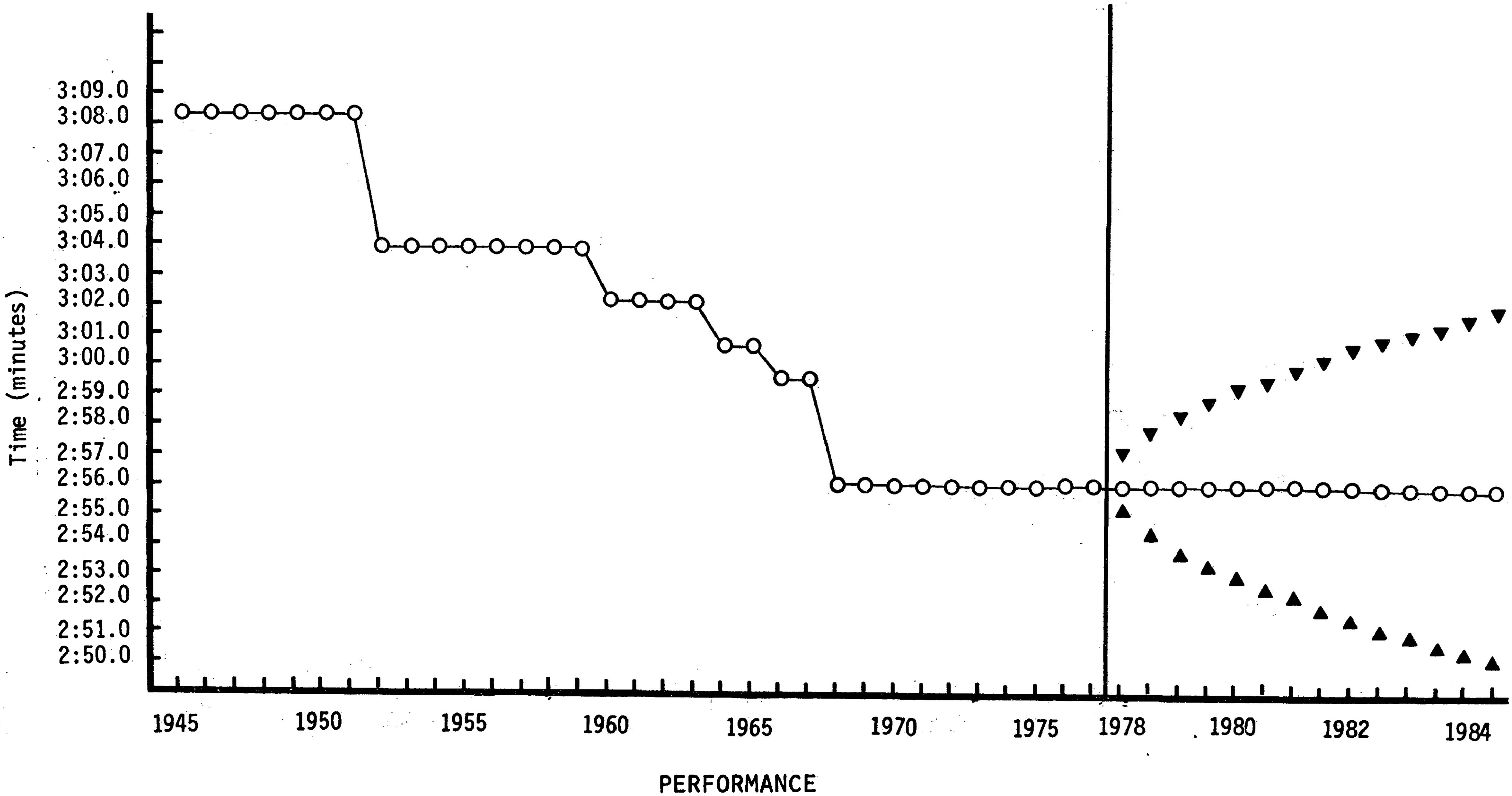
Men's 400 Metre Hurdles



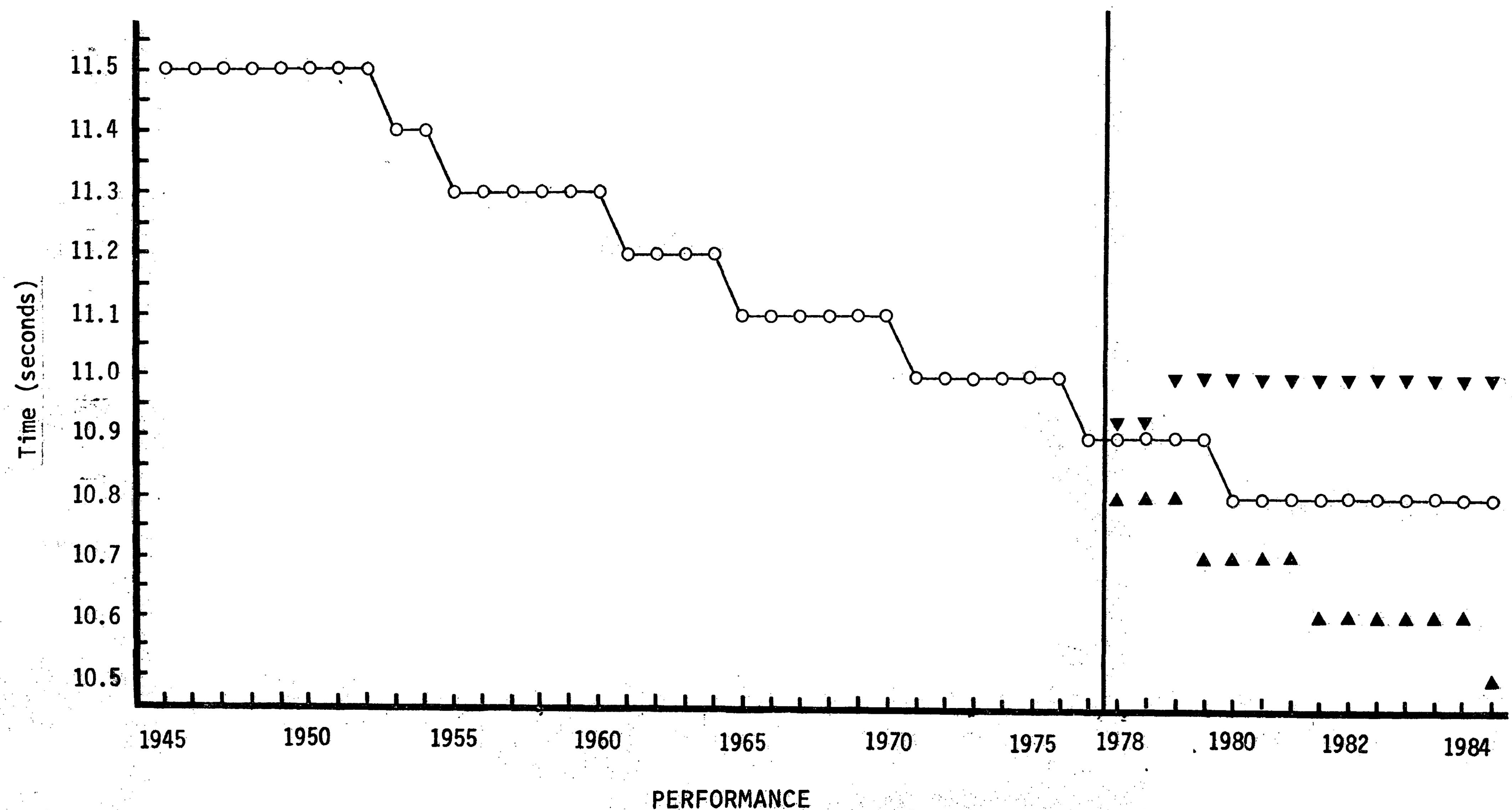
Men's 3,000 Metre Steeplechase



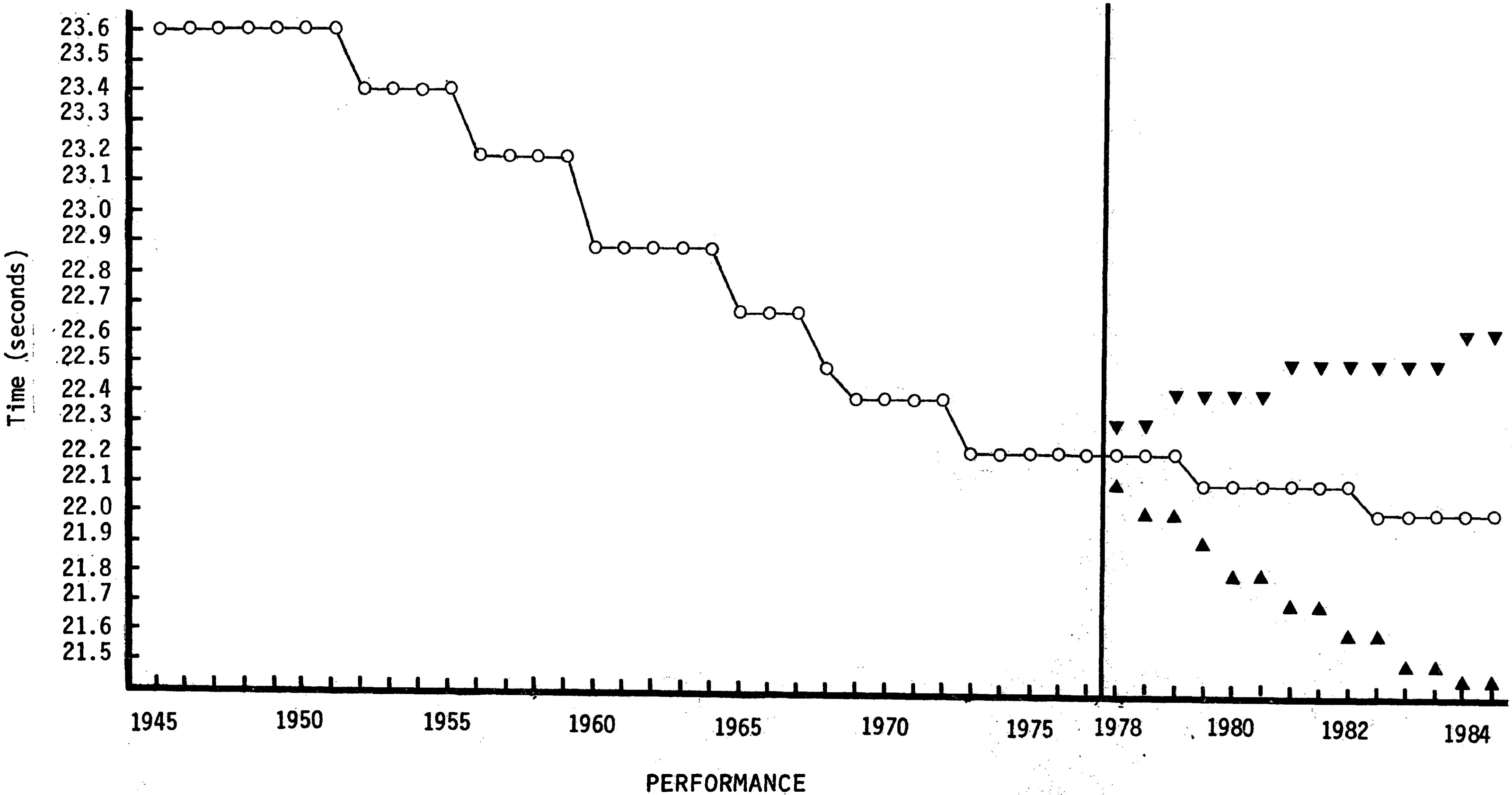
Men's 4 X 100 Metre Relay



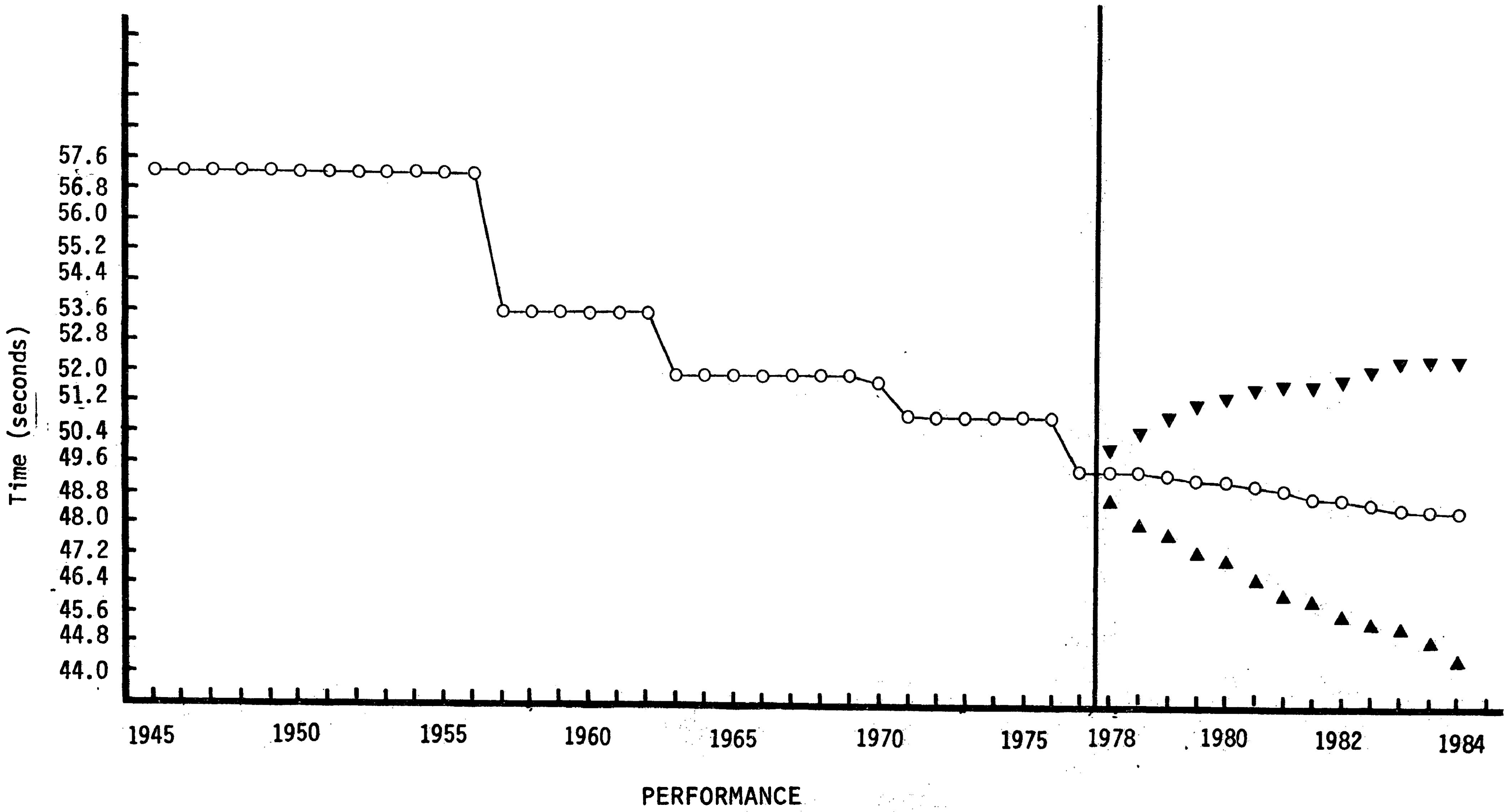
Men's 4 X 400 Metre Relay



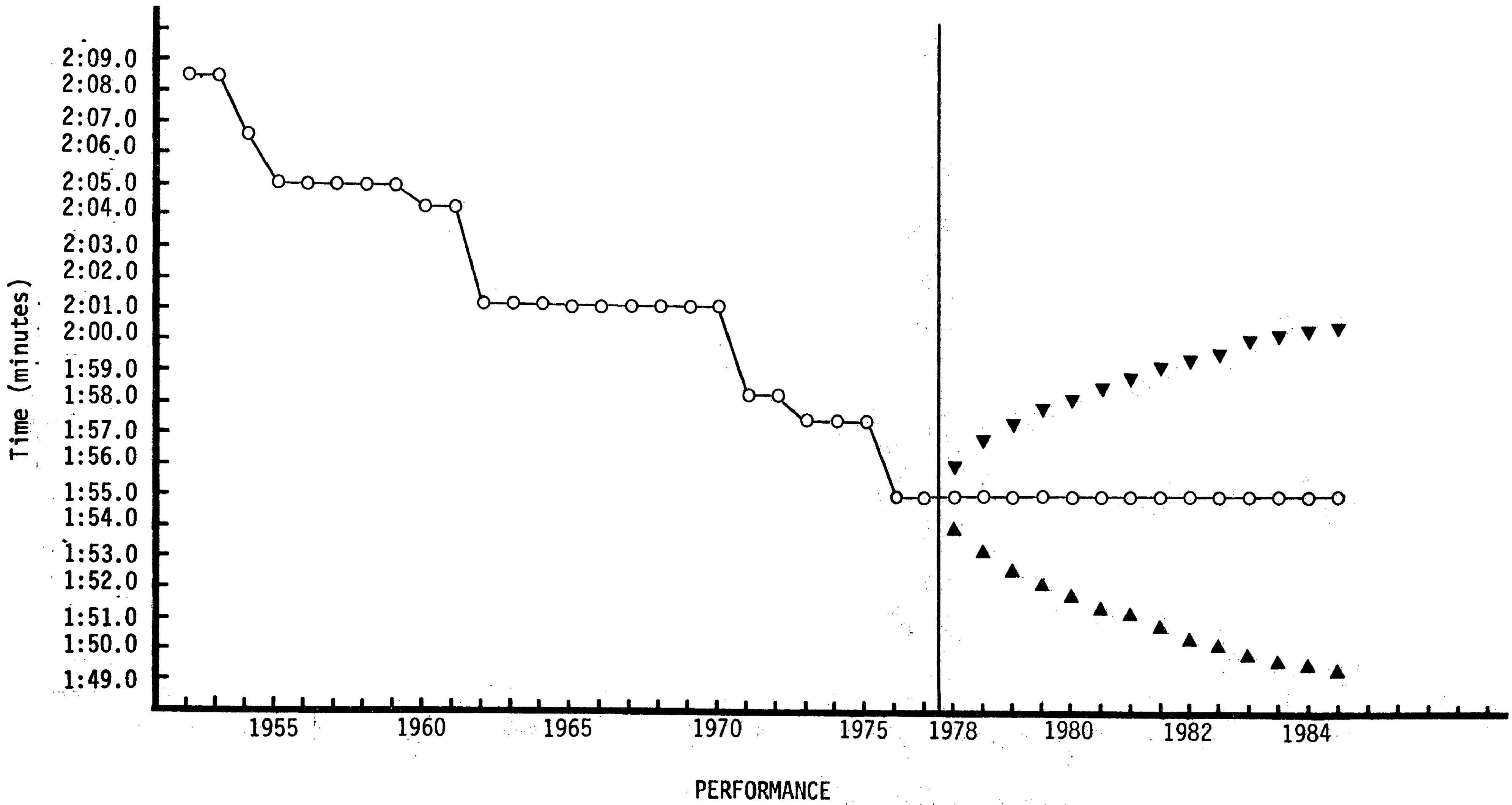
Women's 100 Metre Dash



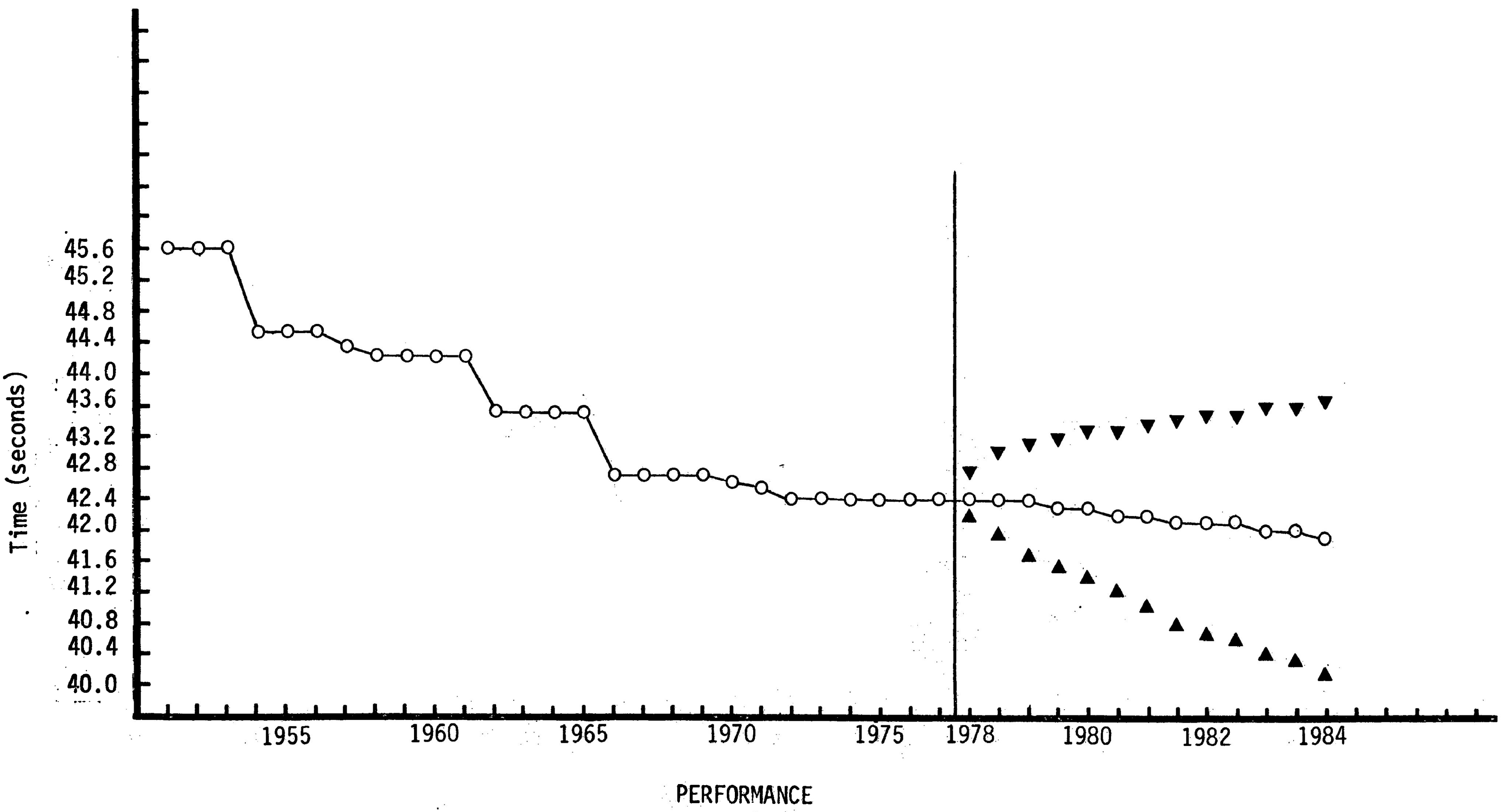
Women's 200 Metre Dash



Women's 400 Metre Dash



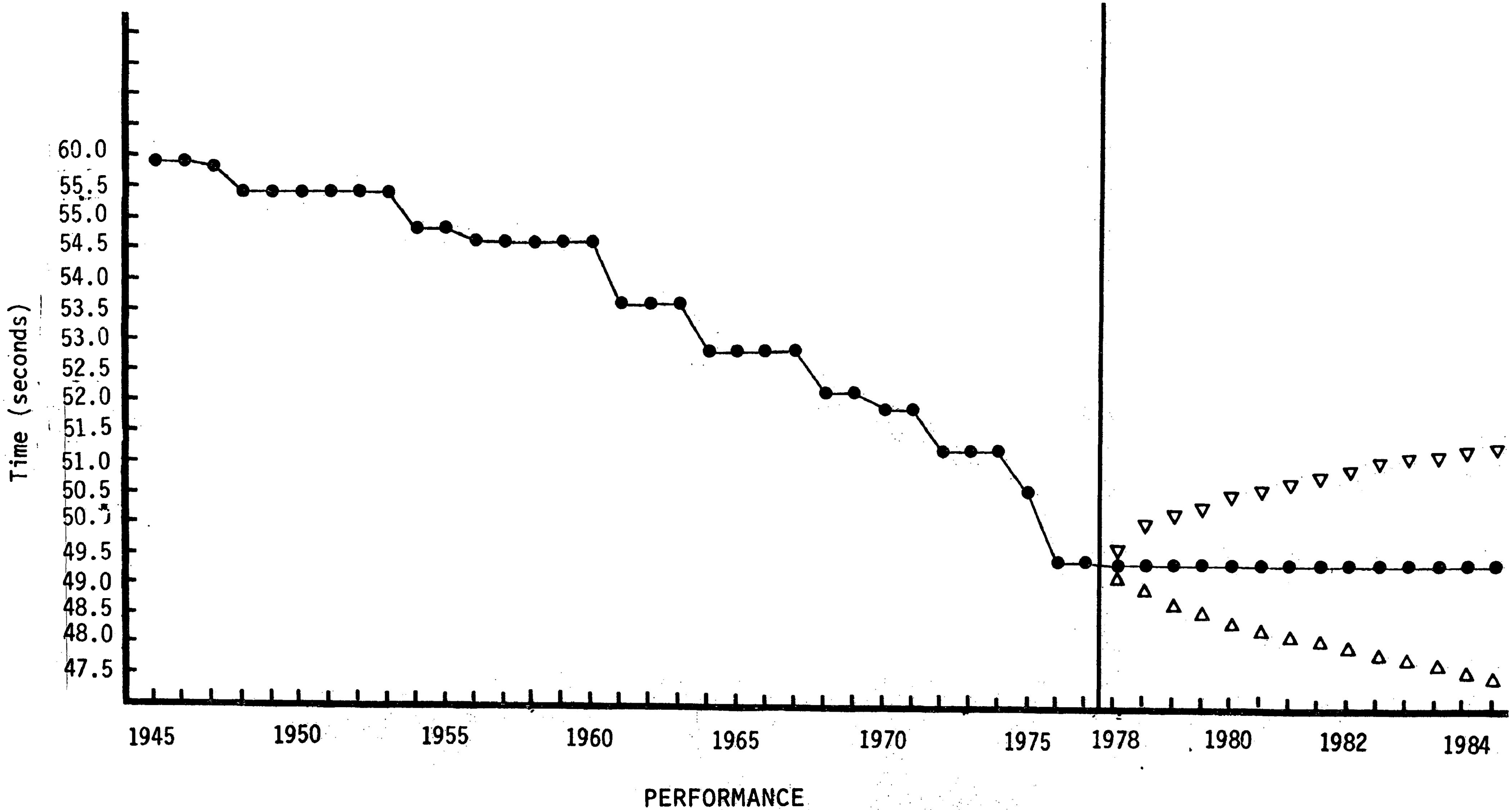
Women's 800 Metre Run



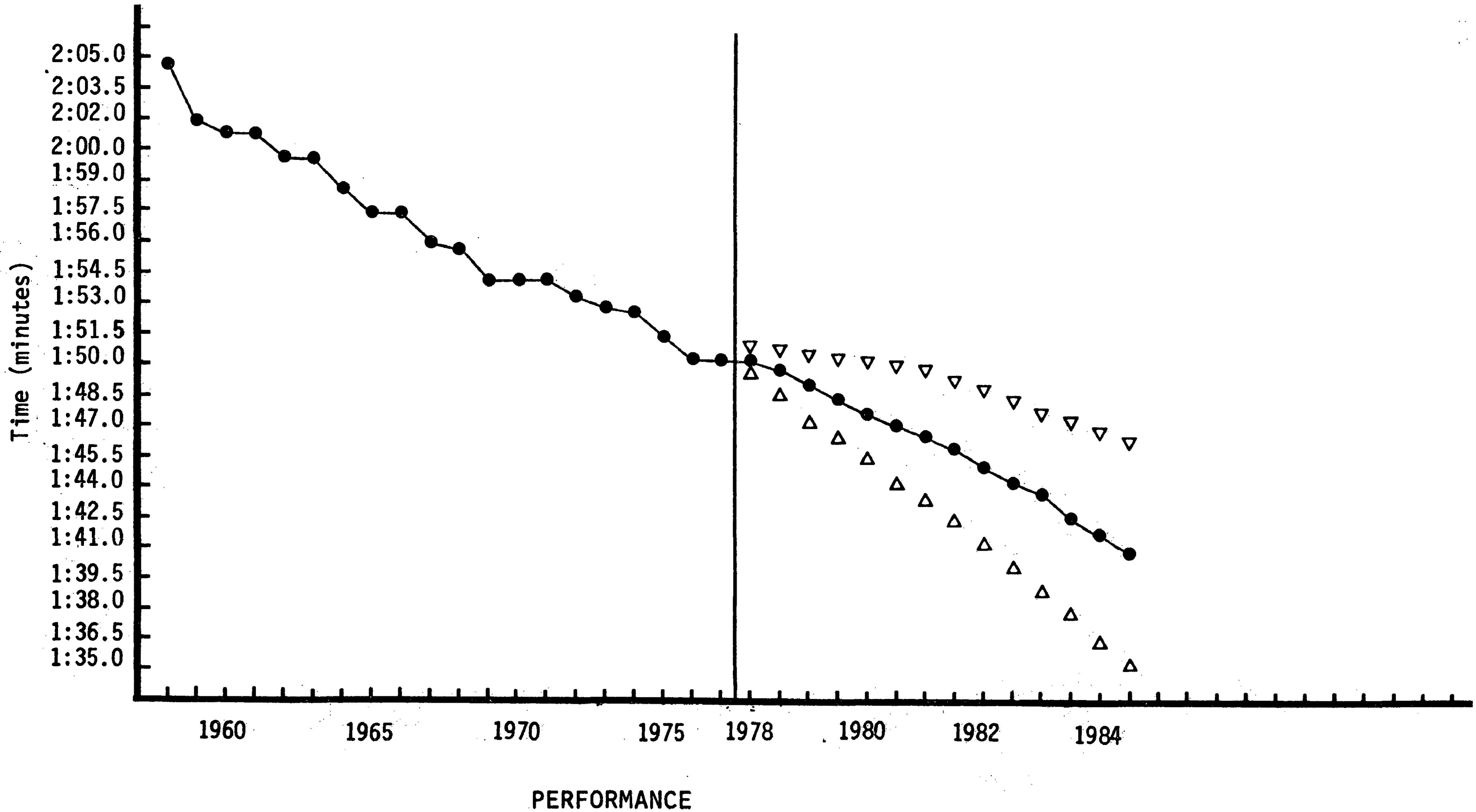
Women's 4 X 100 Metre Relay

Appendix C

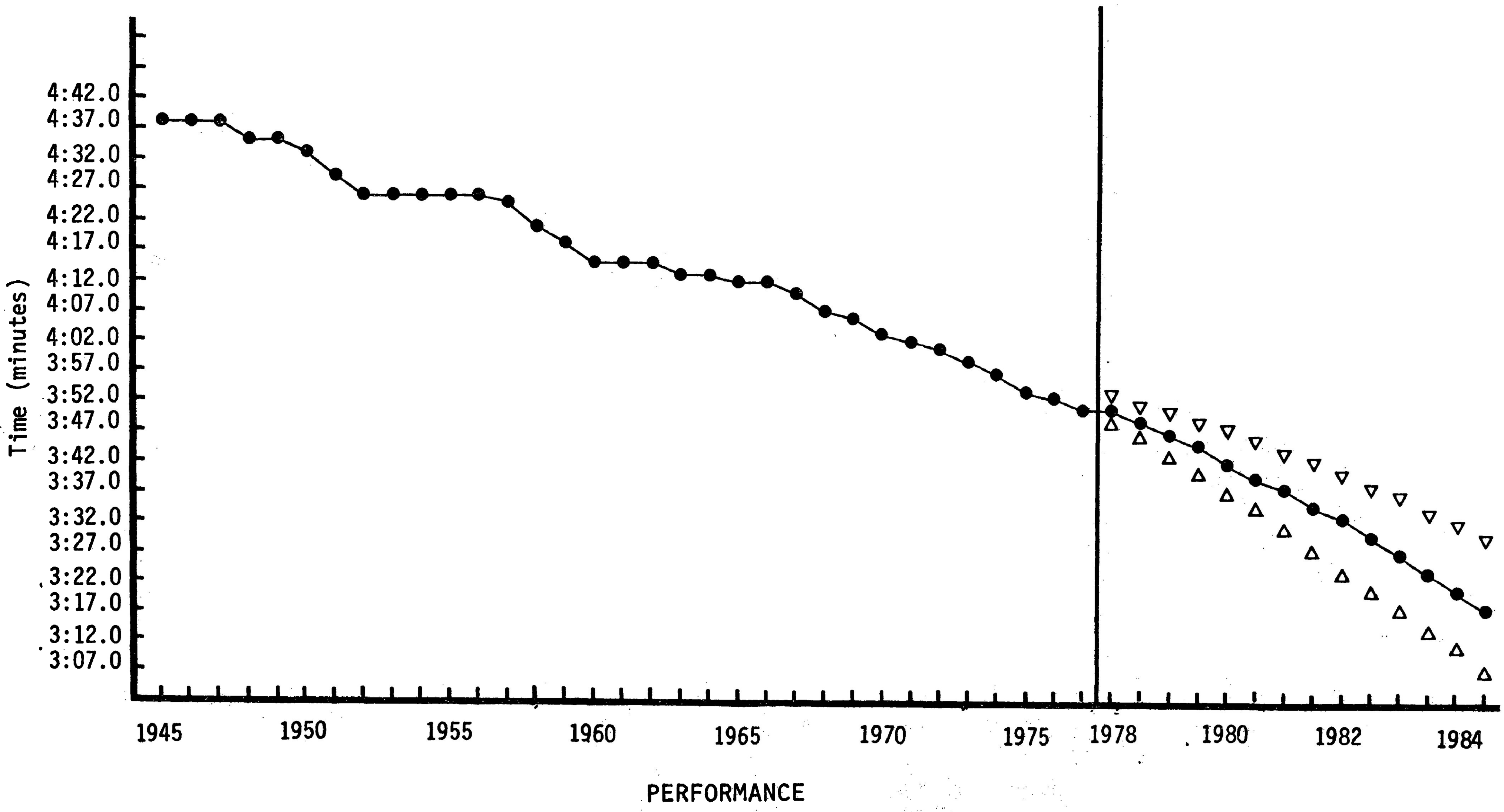
Graphs for swimming events



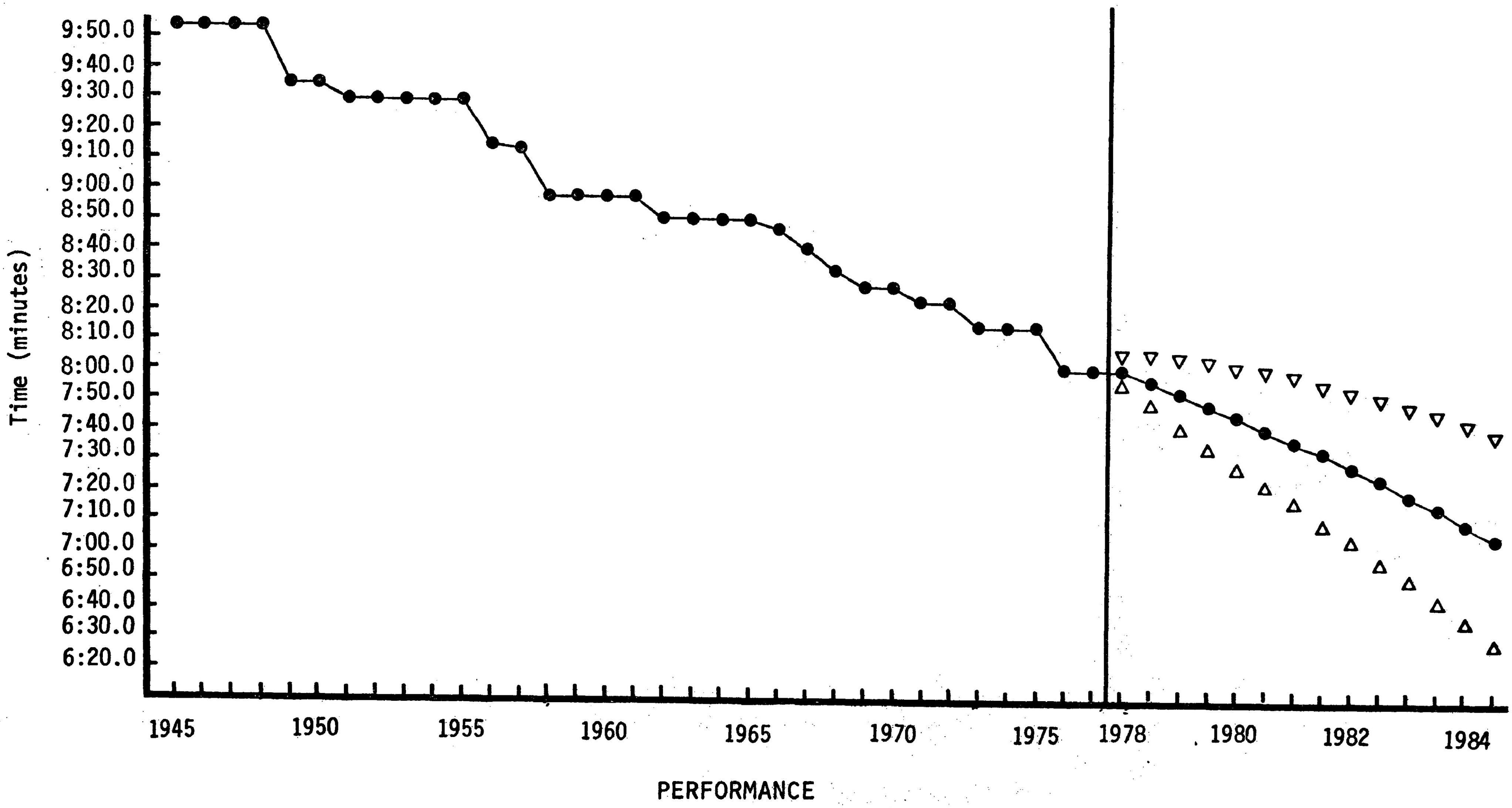
Men's 100 Metre Free-style



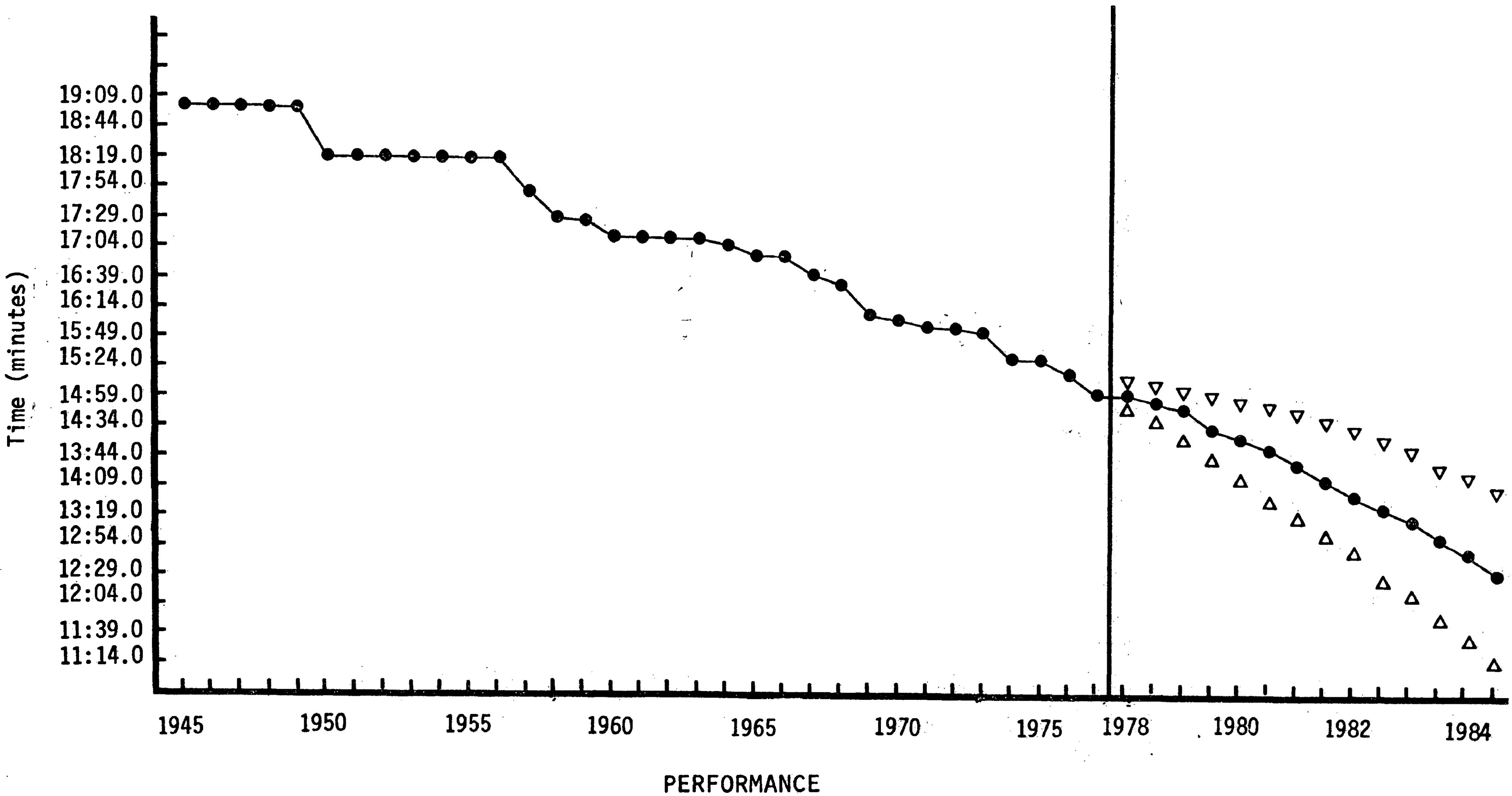
Men's 200 Metre Free-style



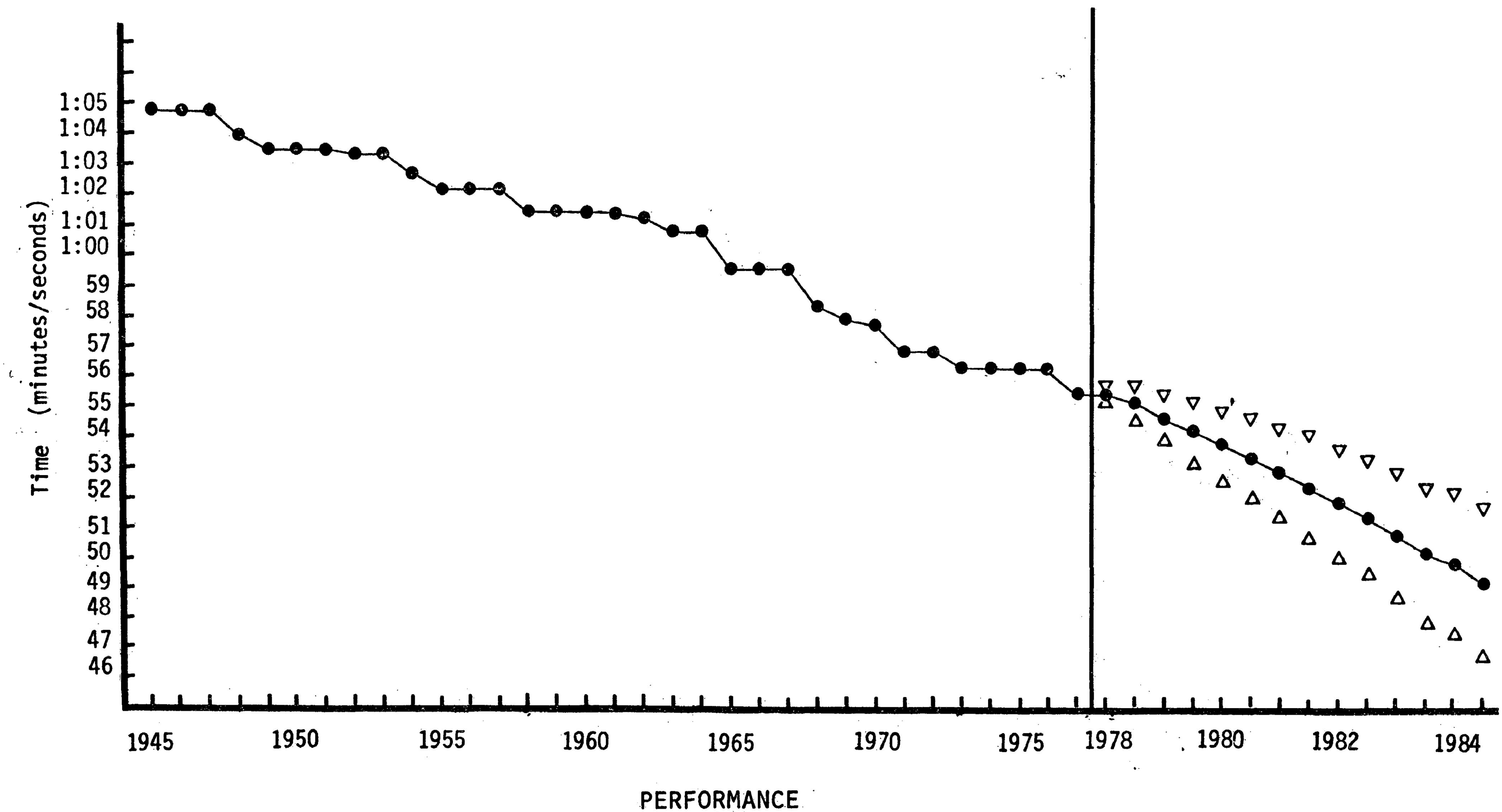
Men's 400 Metre Free-style



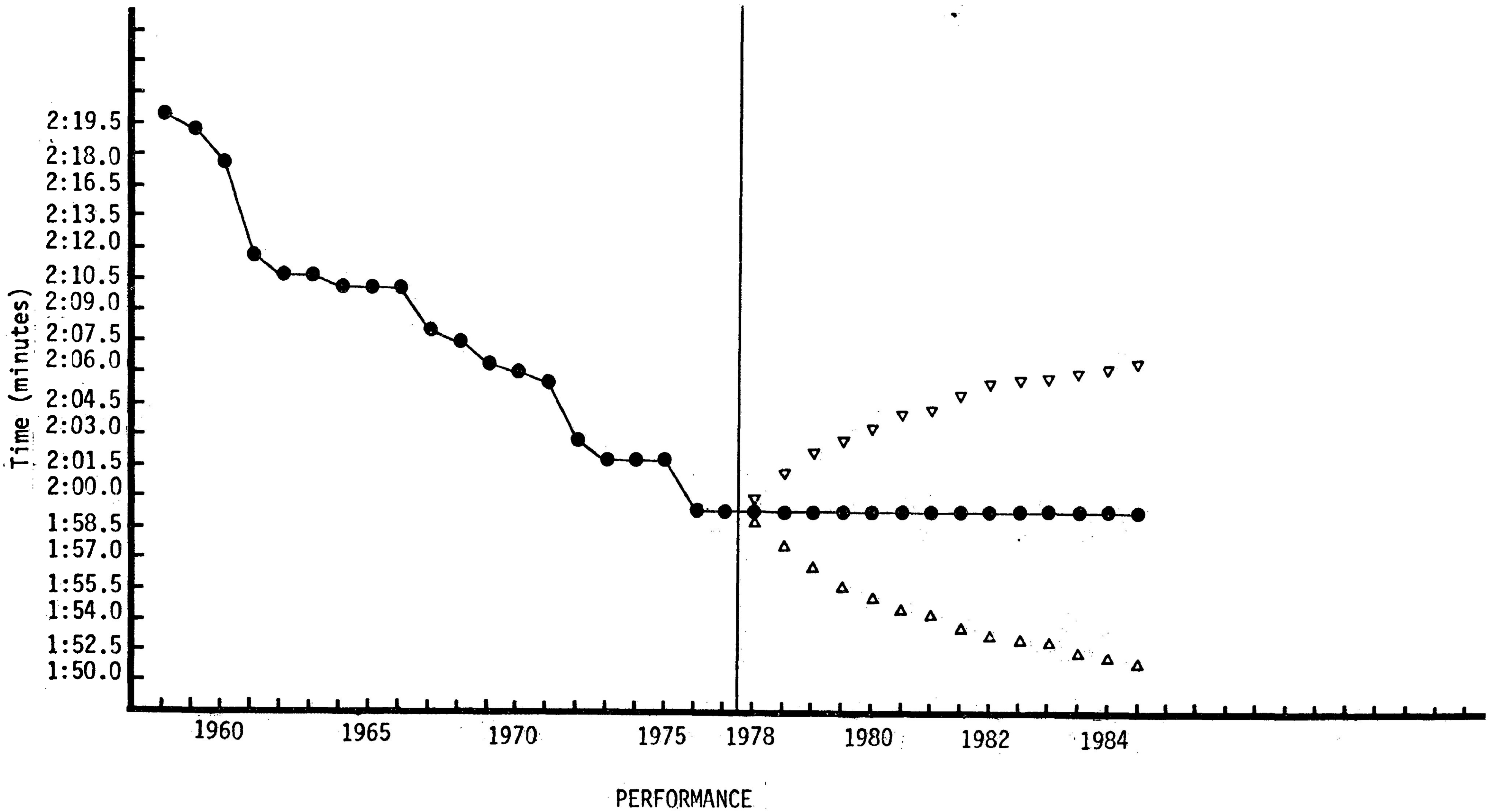
Men's 800 Metre Free-style



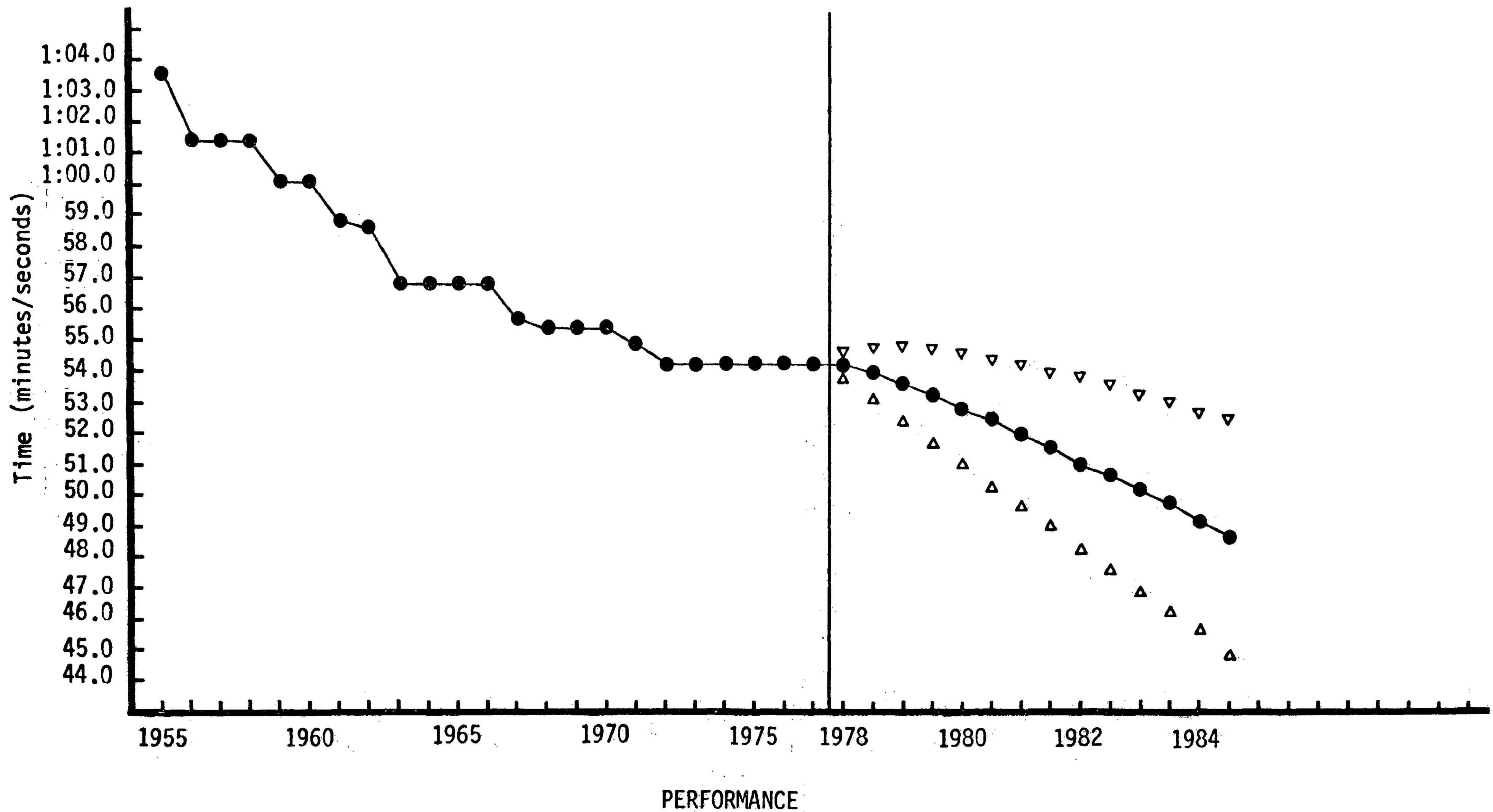
Men's 1,500 Metre Free-style



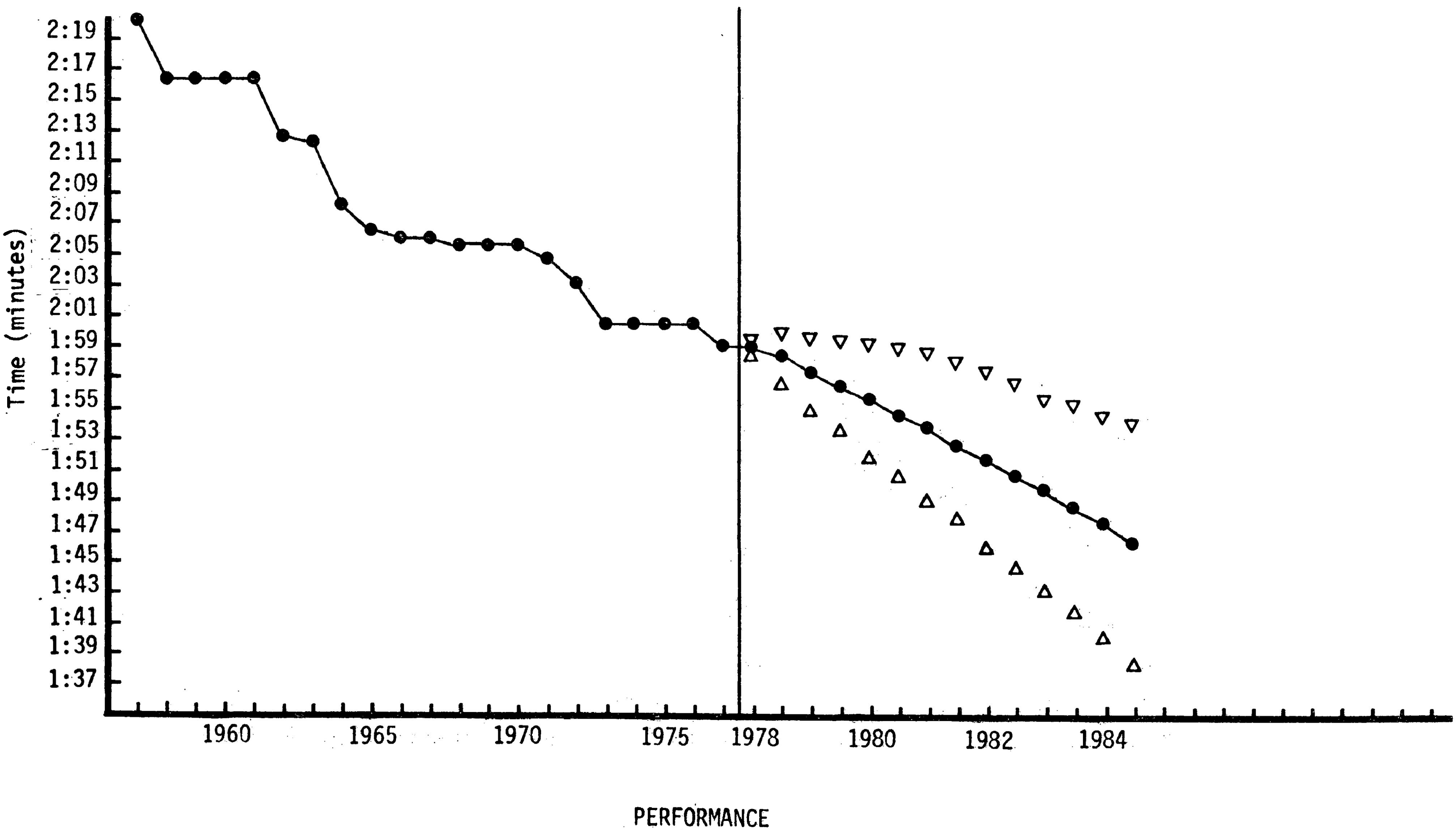
Men's 100 Metre Back-stroke



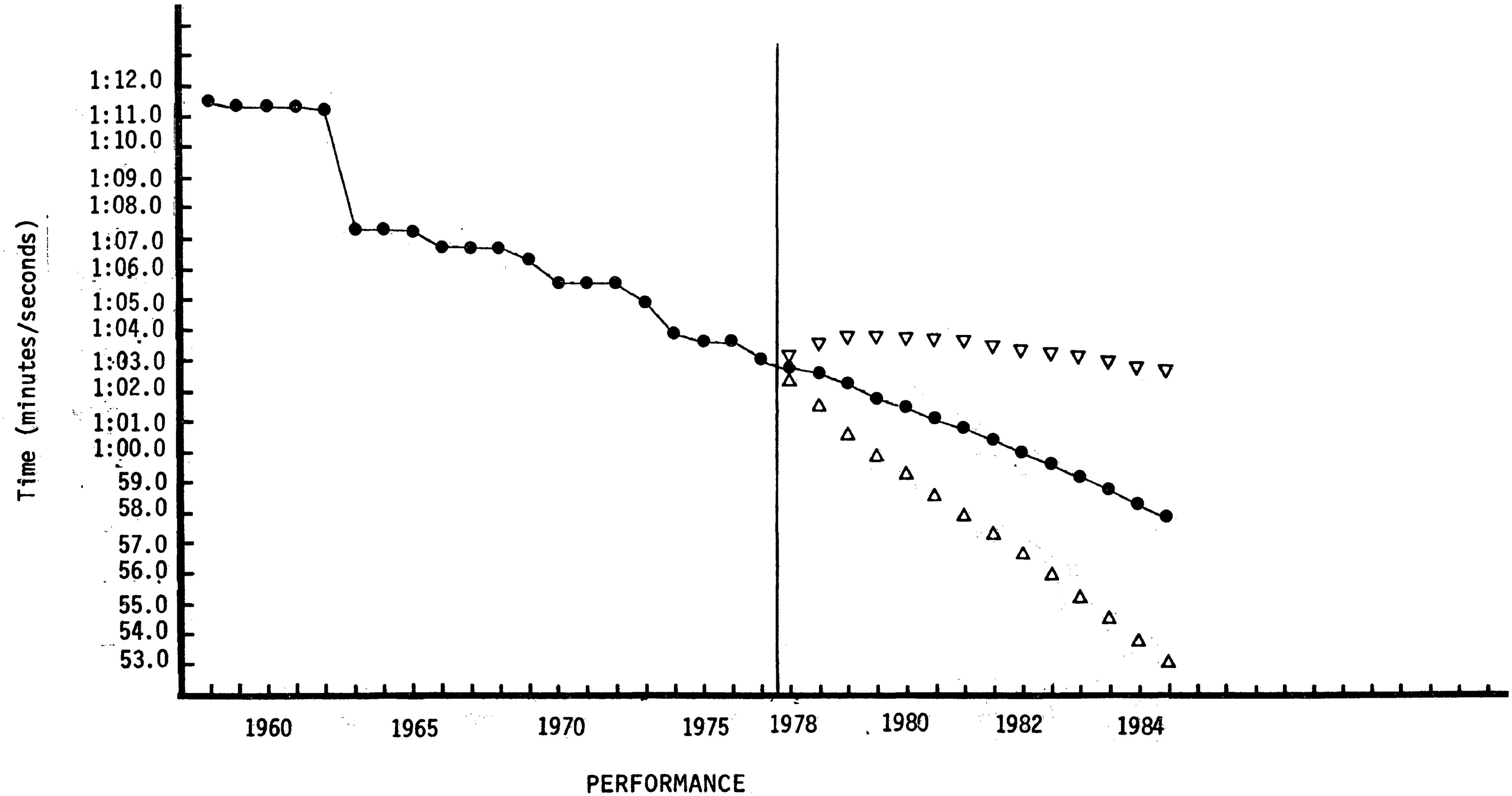
Men's 200 Metre Back-stroke



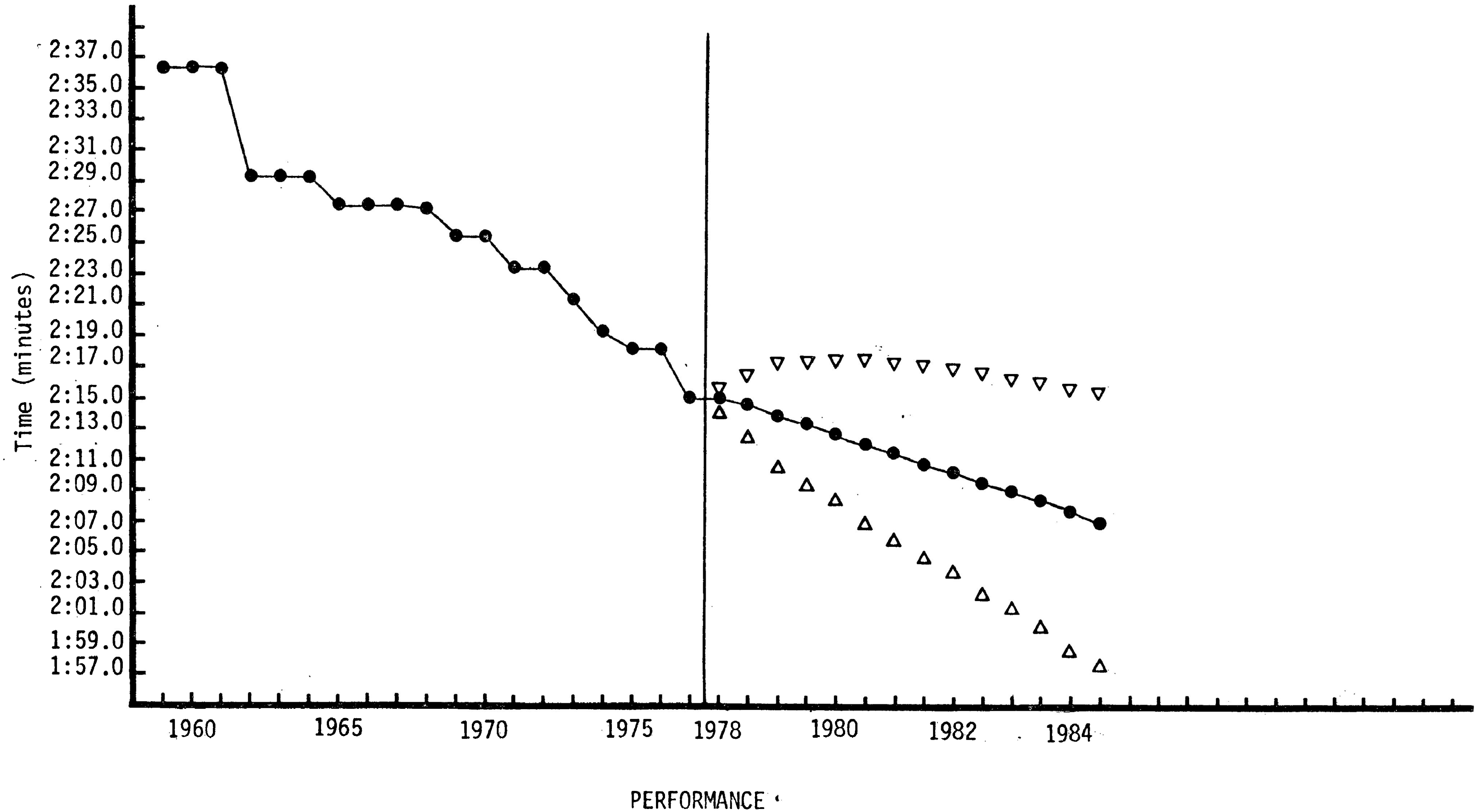
Men's 100 Metre Butterfly



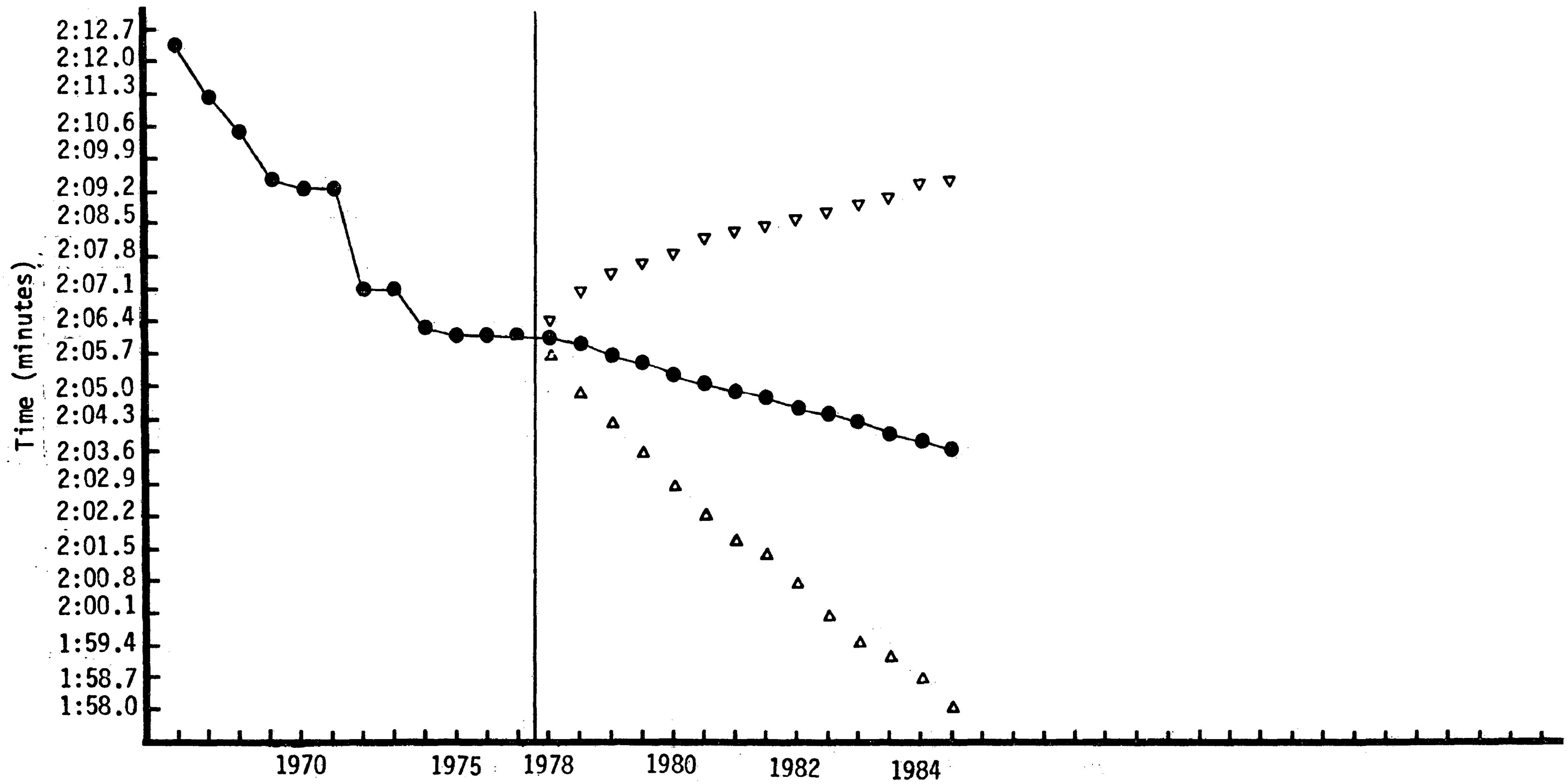
Men's 200 Metre Butterfly



Men's 100 Metre Breast-stroke

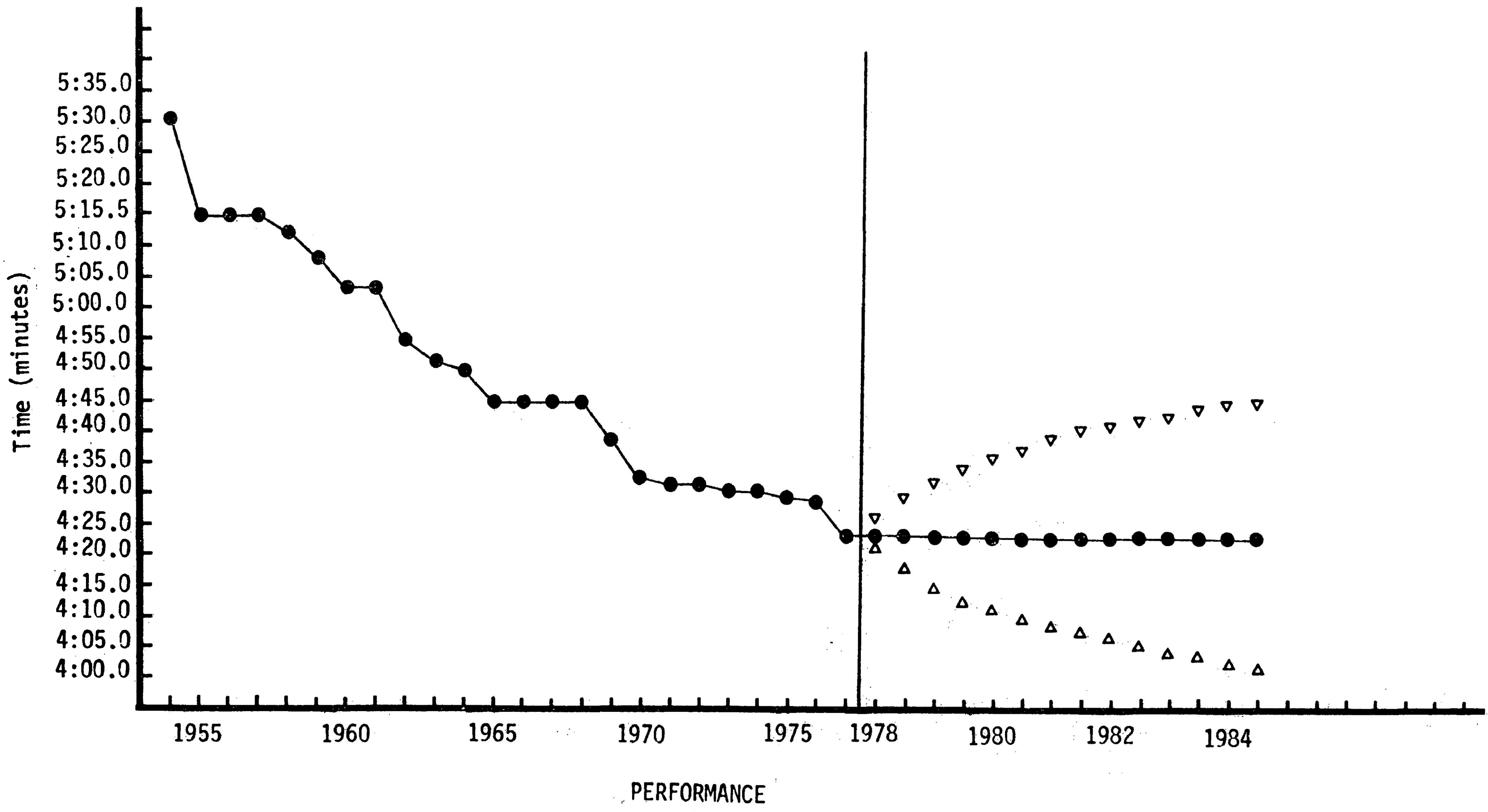


Men's 200 Metre Breast-stroke

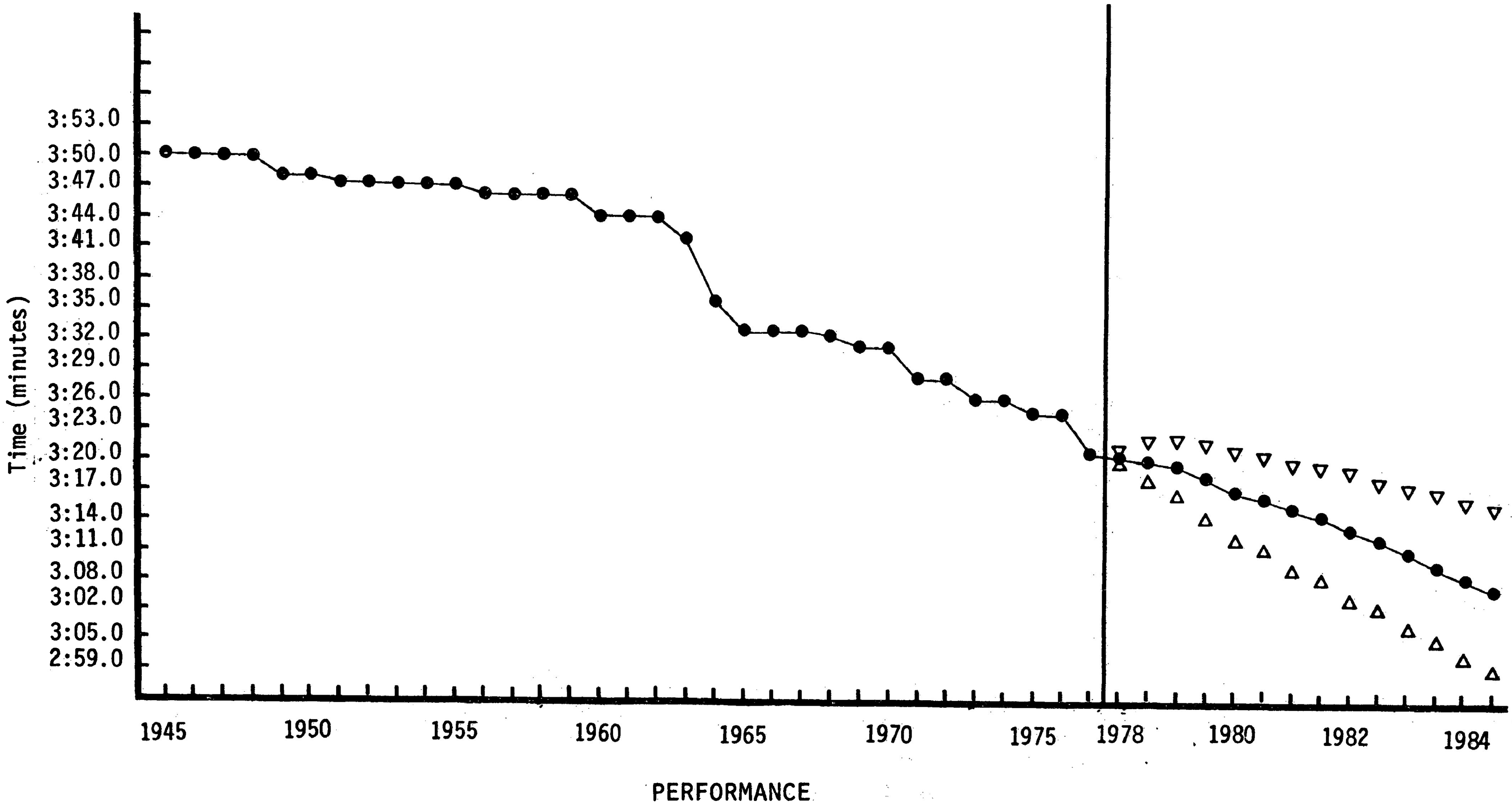


PERFORMANCE

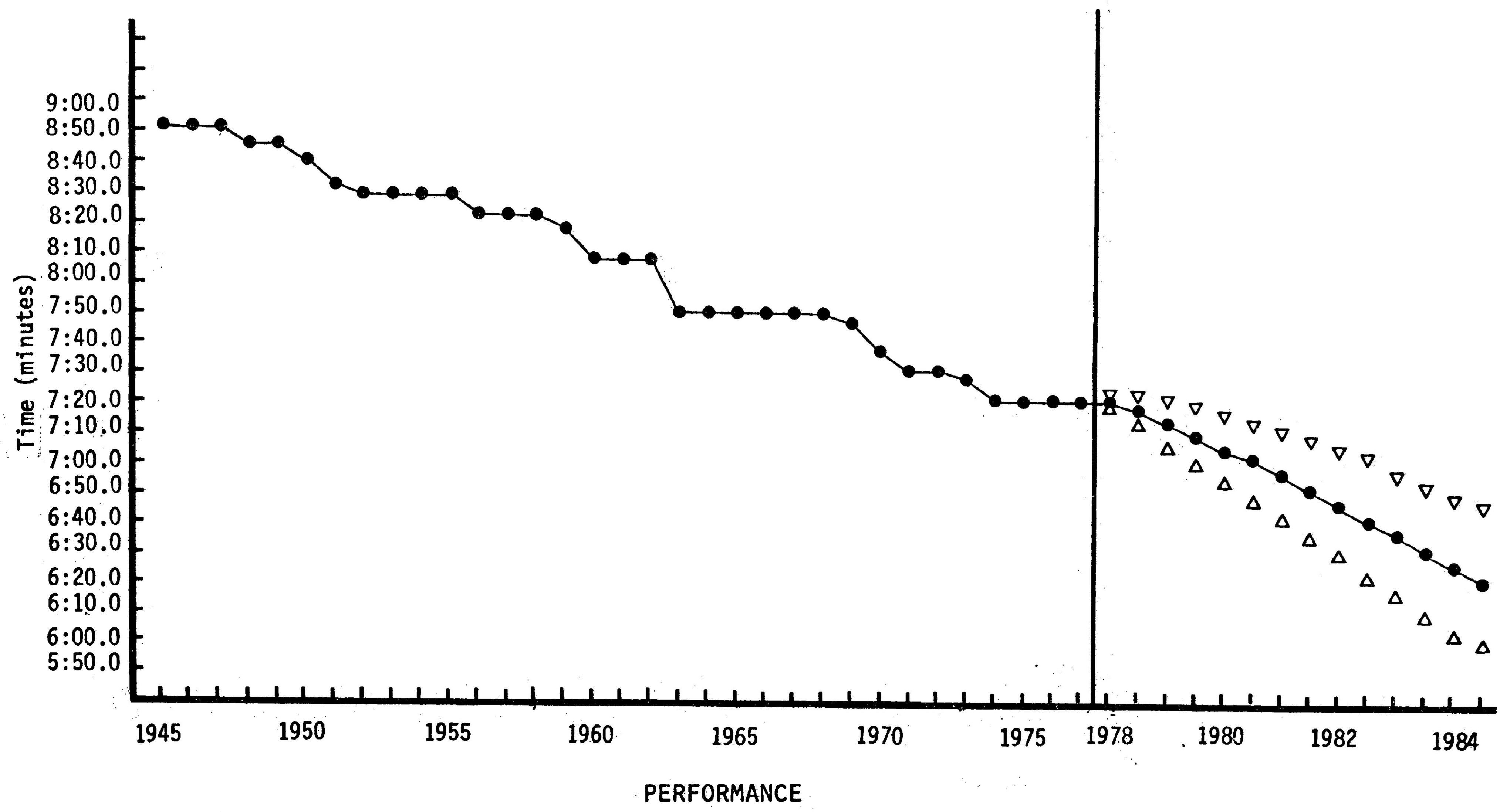
Men's 200 Metre Individual Medley



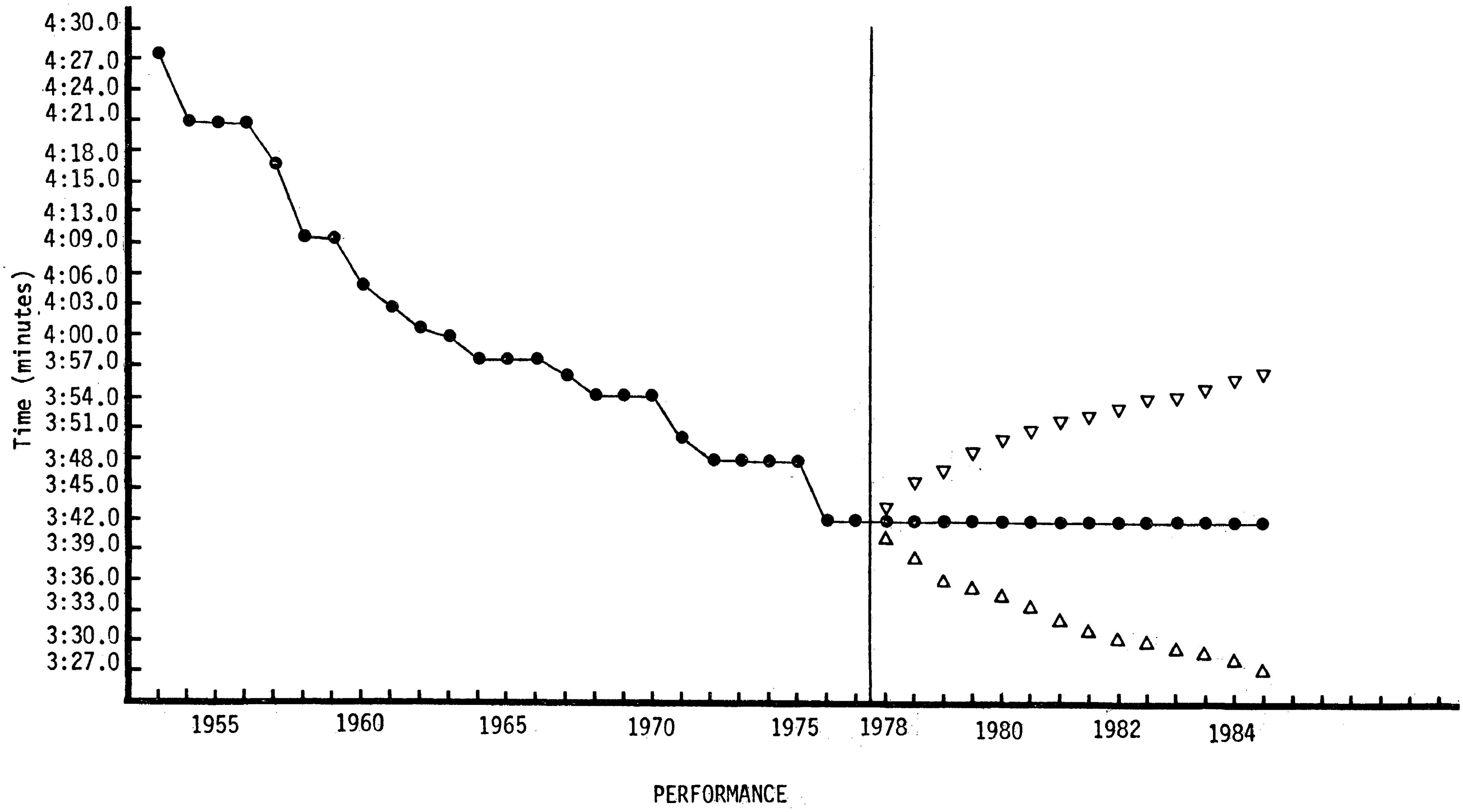
Men's 400 Metre Individual Medley



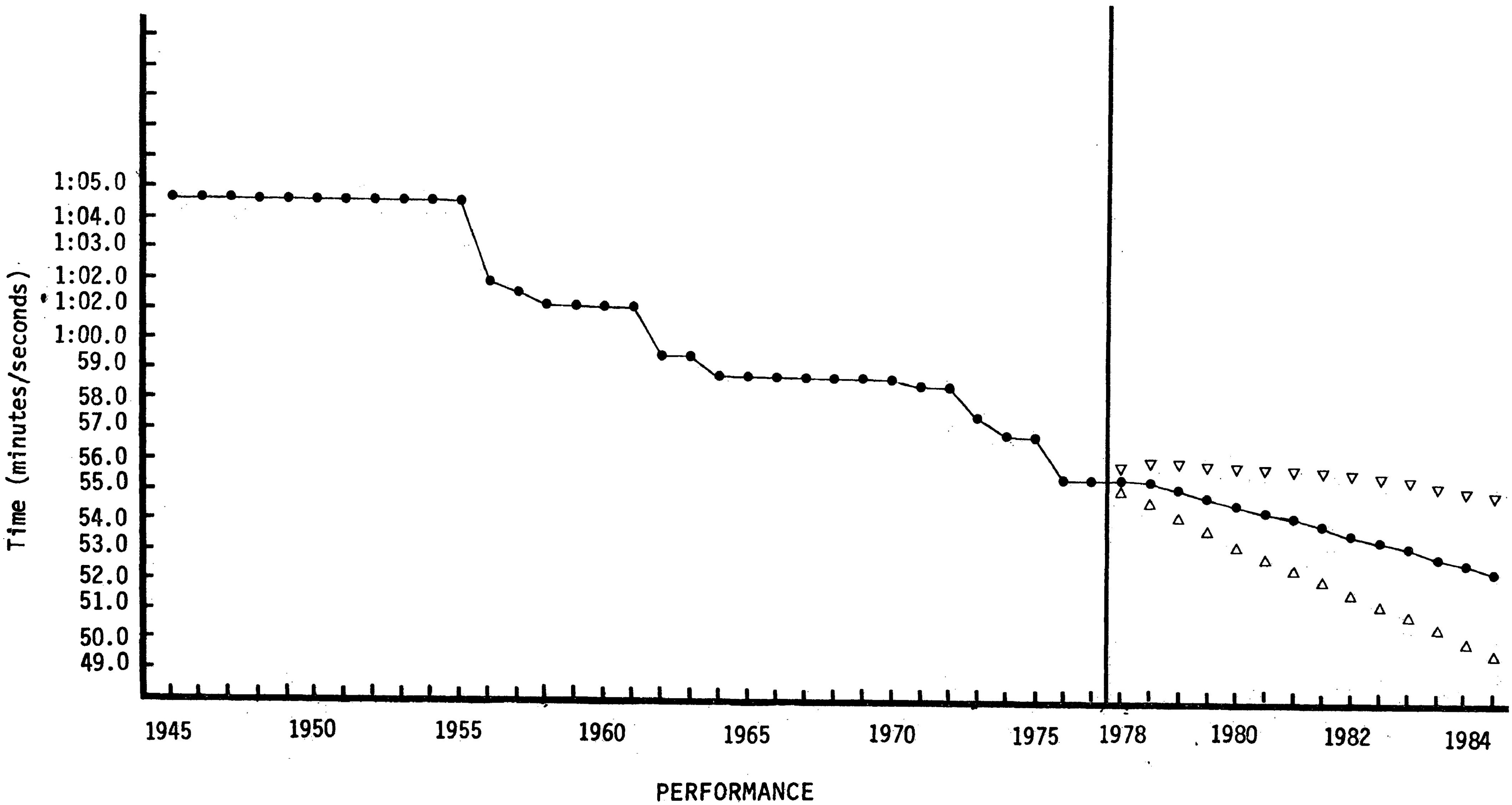
Men's 4 X 100 Metre Free-style Relay



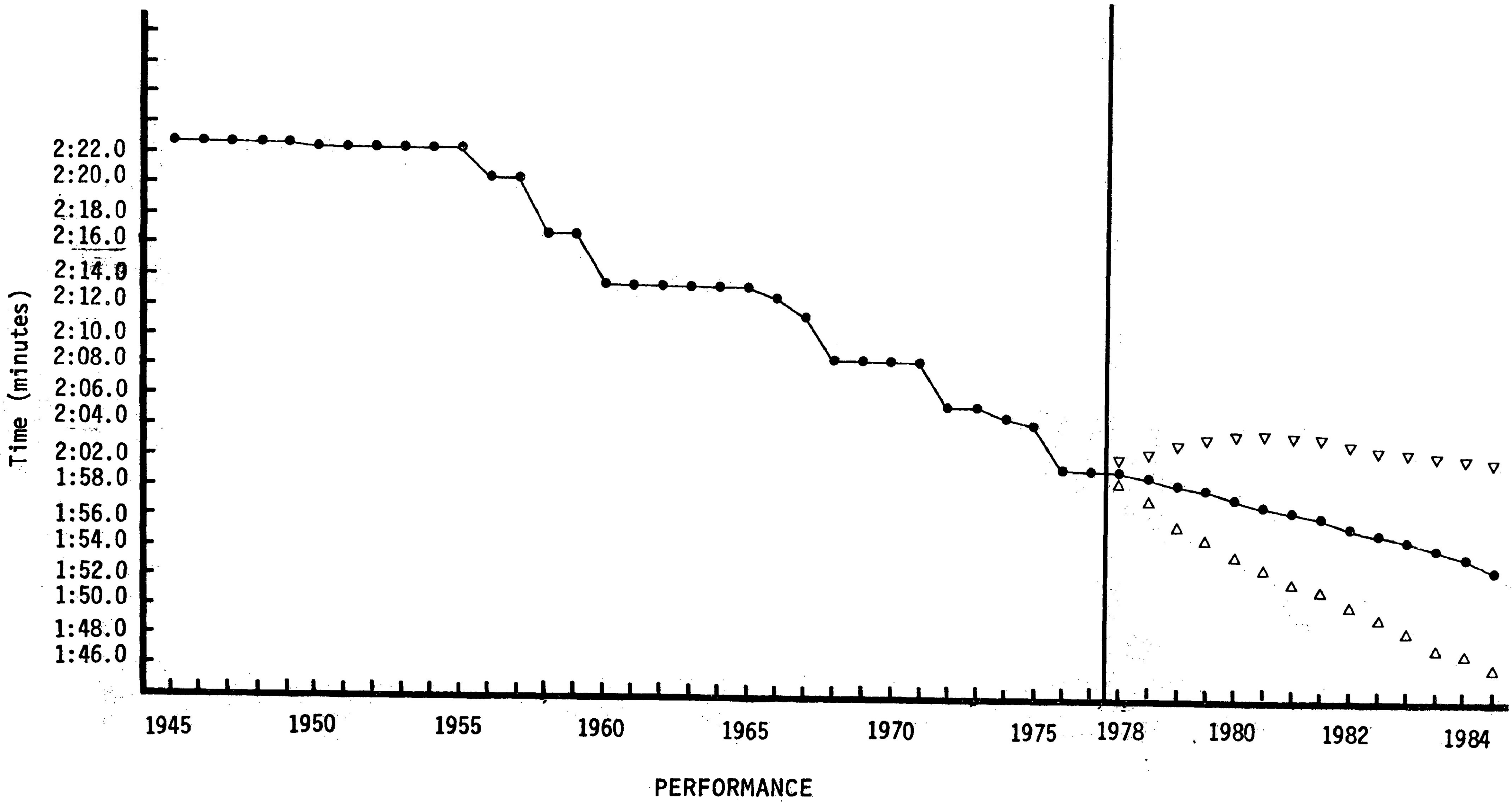
Men's 4 X 200 Free-style Relay



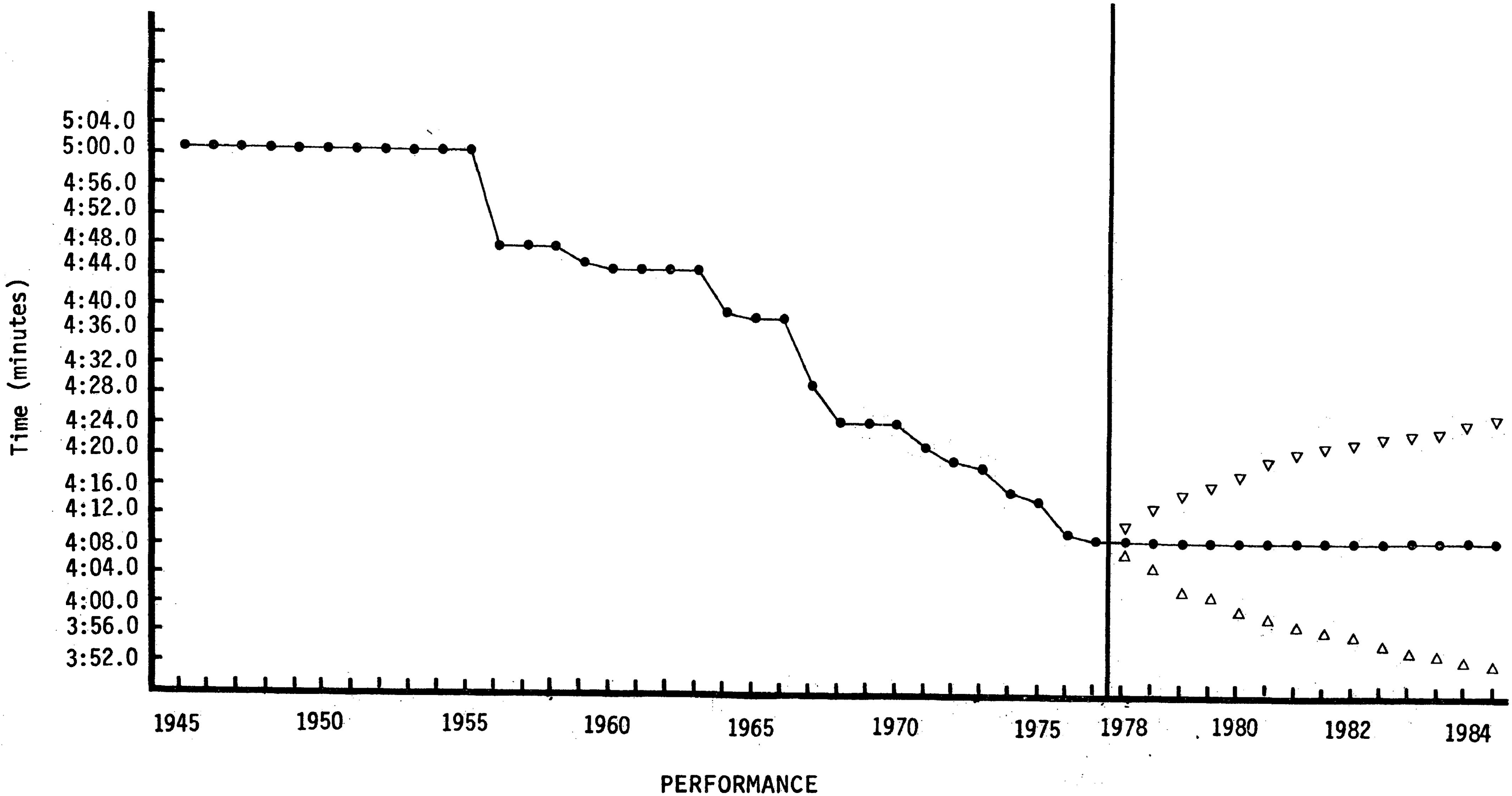
Men's 4 X 100 Metre Medley Relay



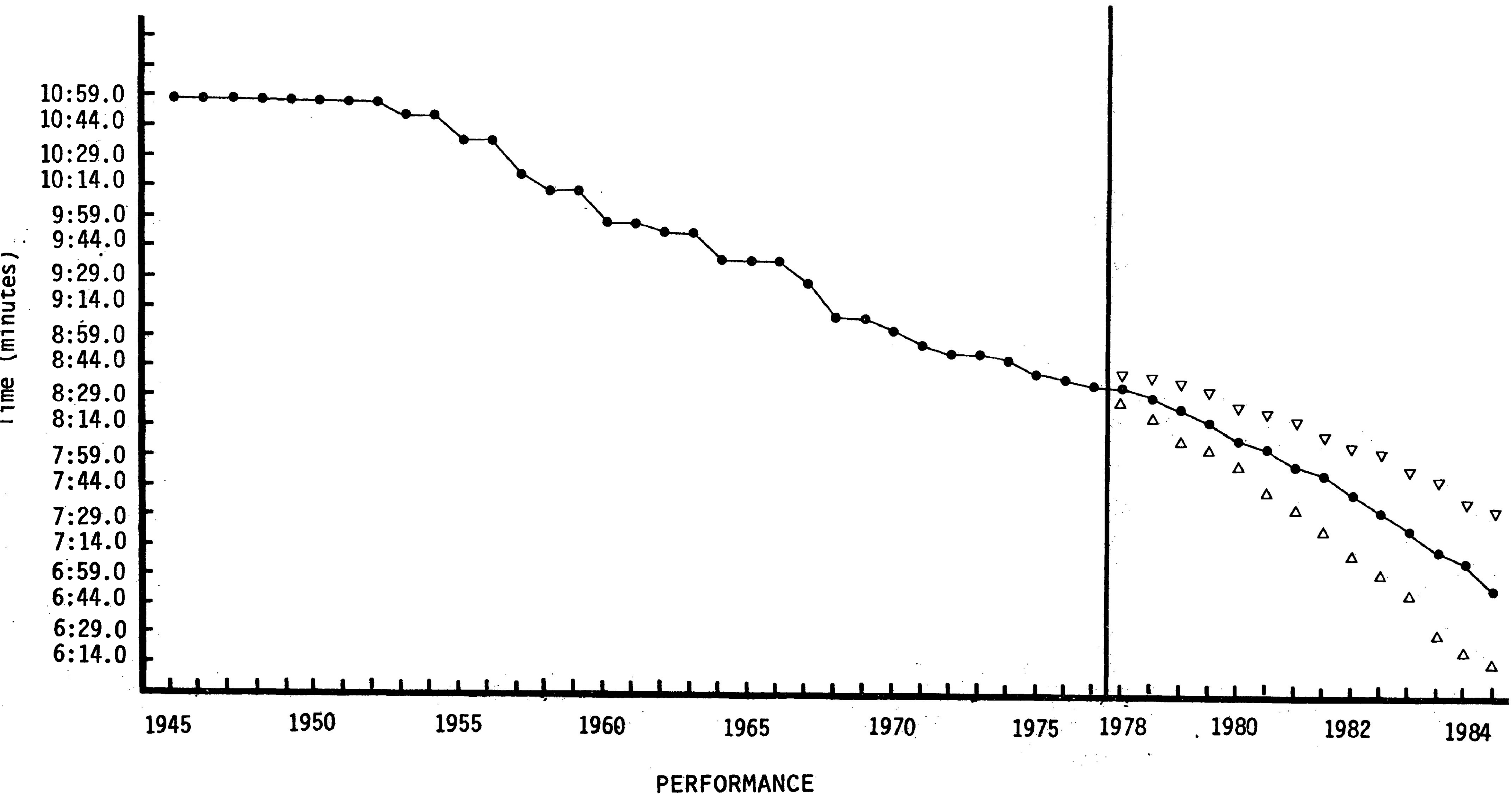
Women's 100 Metre Free-style



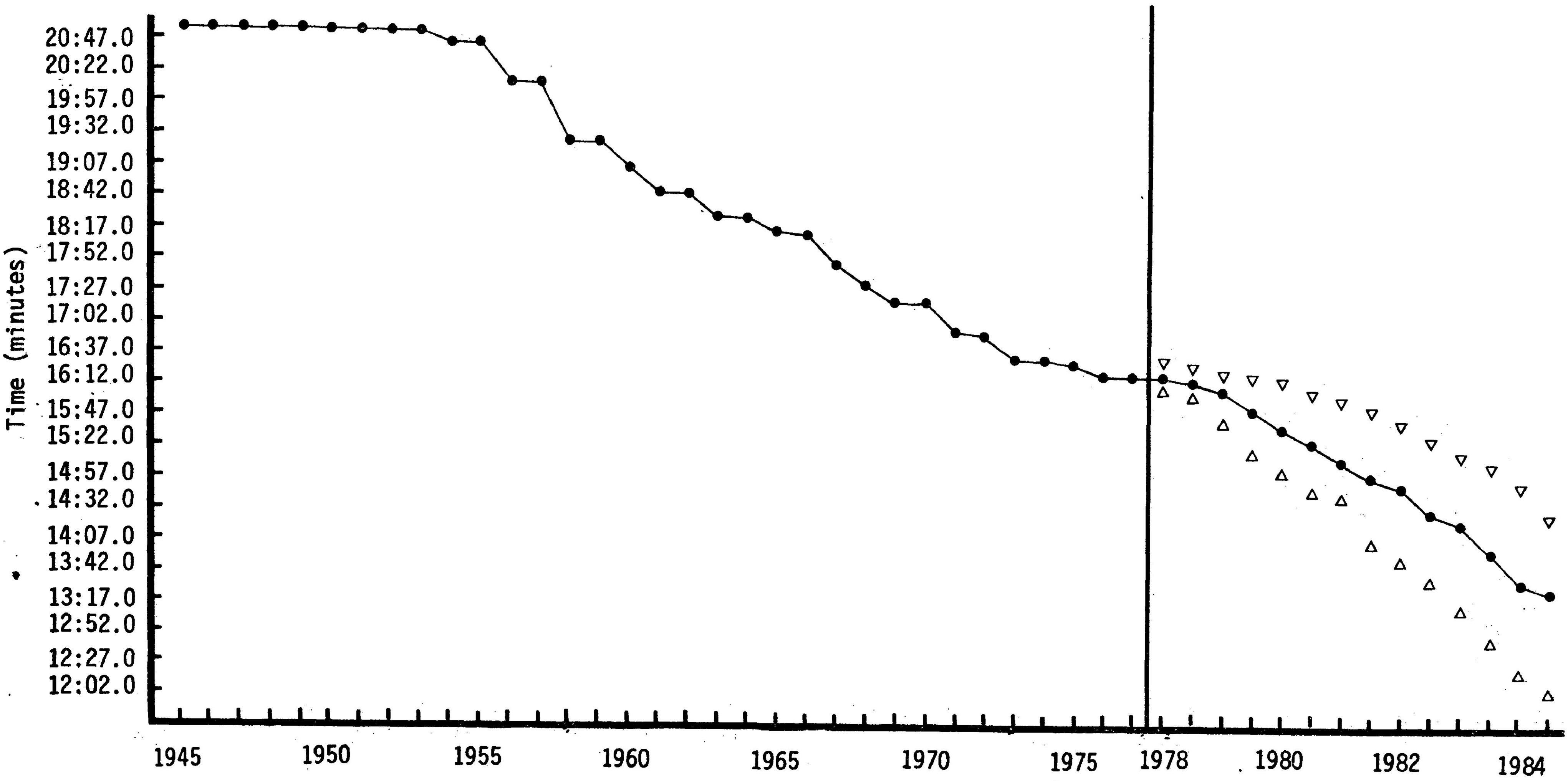
Women's 200 Metre Free-style



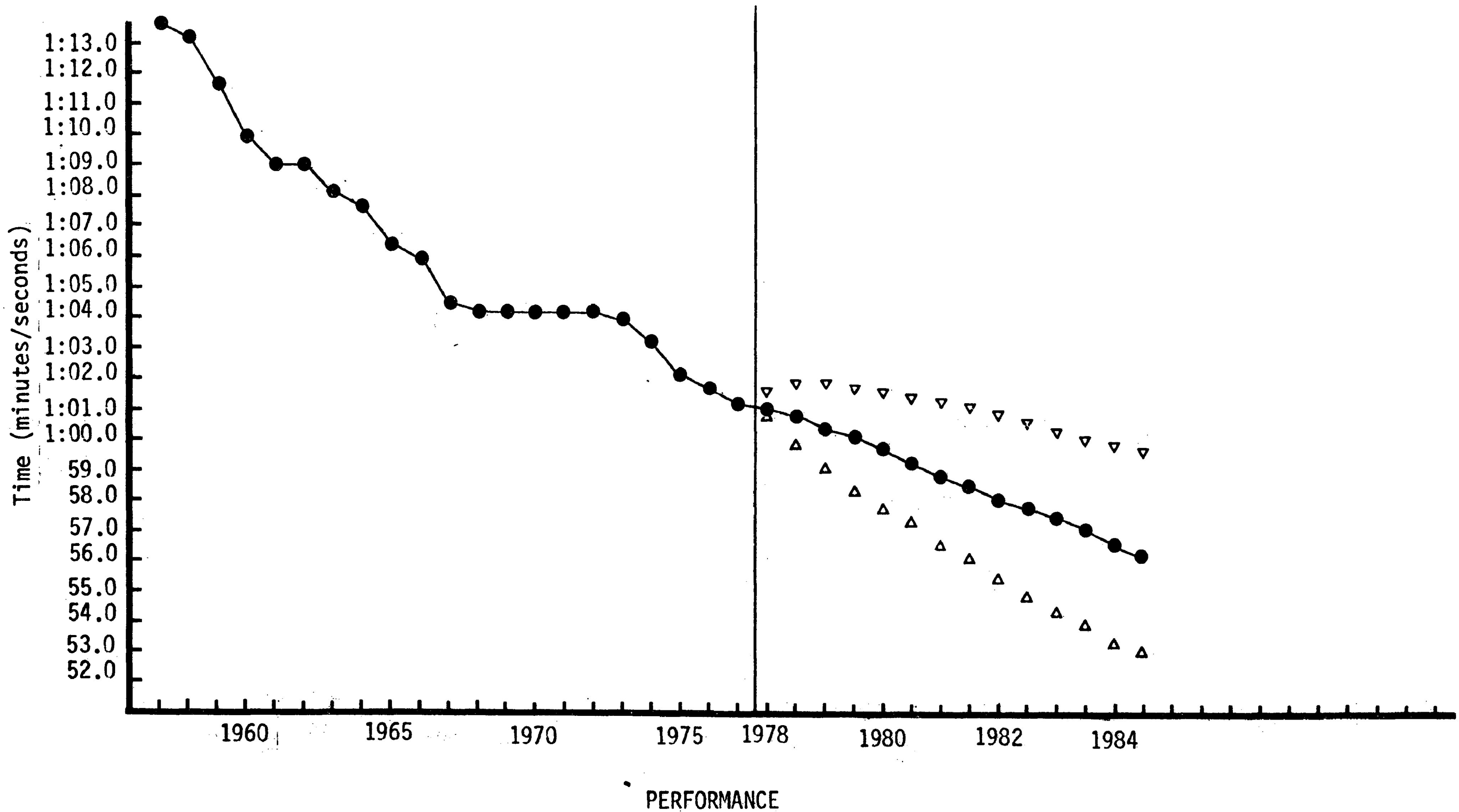
Women's 400 Metre Free-style



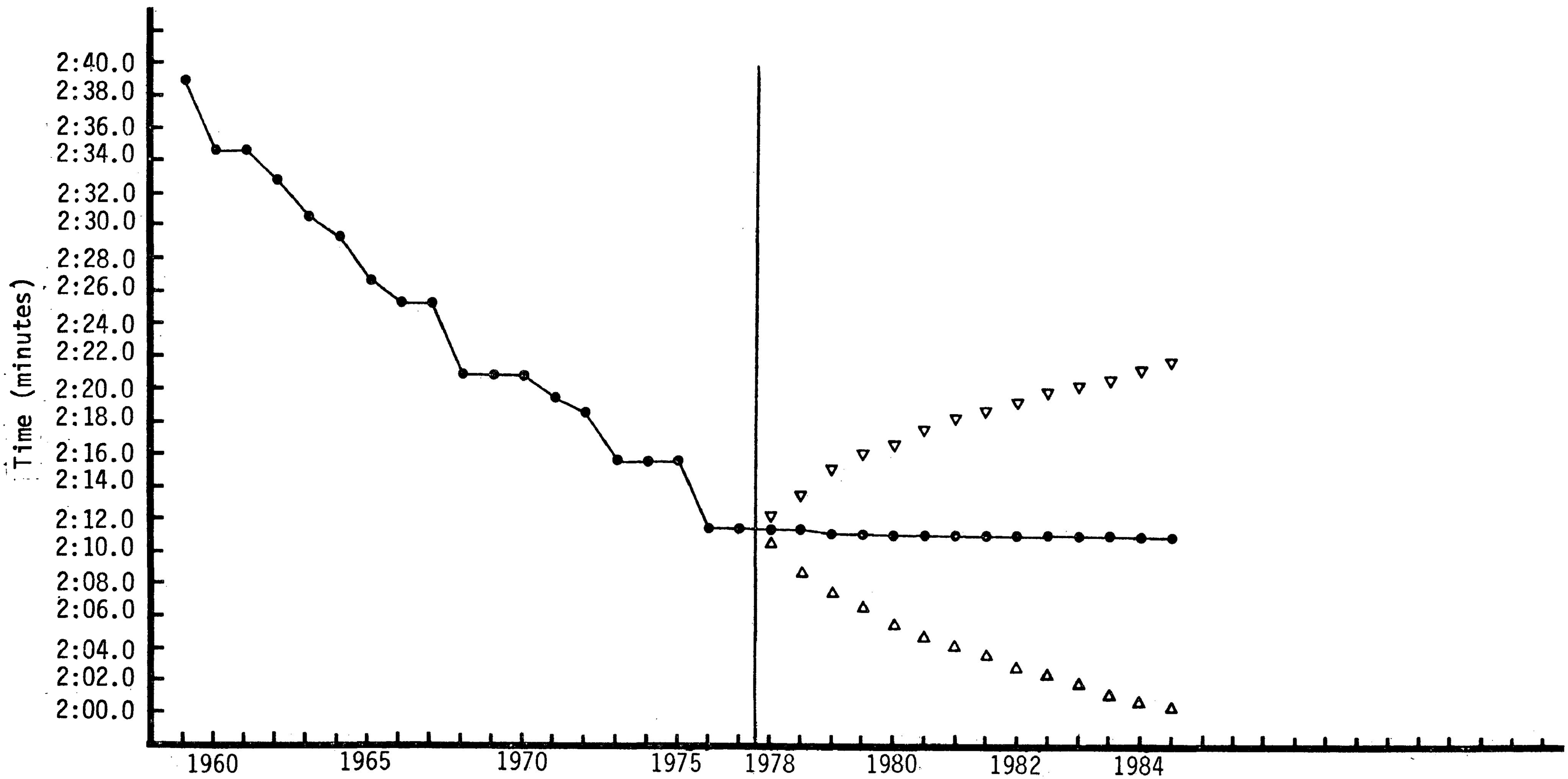
Women's 800 Metre Free-style



Women's 1,500 Metre Free-style

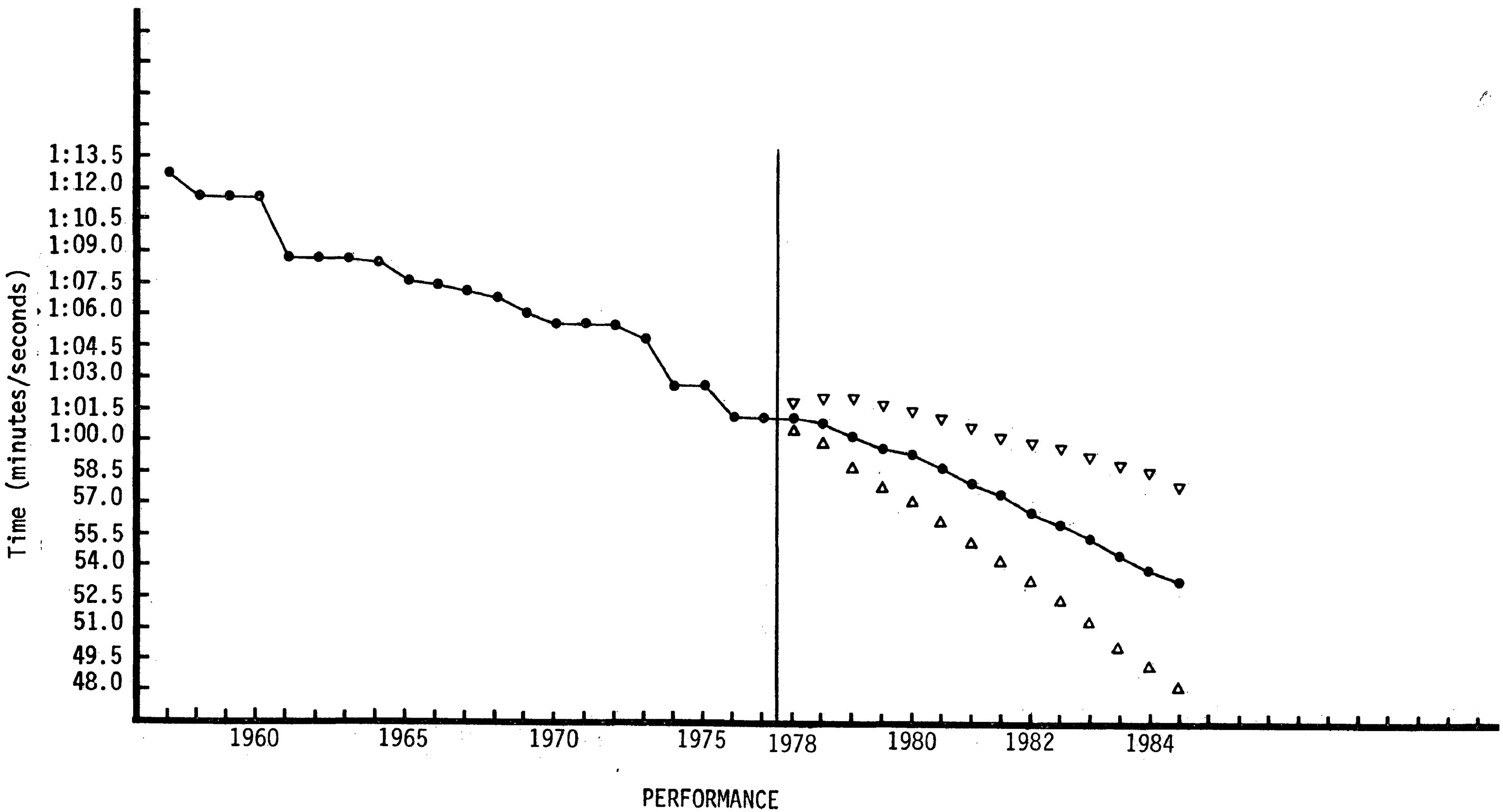


Women's 100 Metre Butterfly

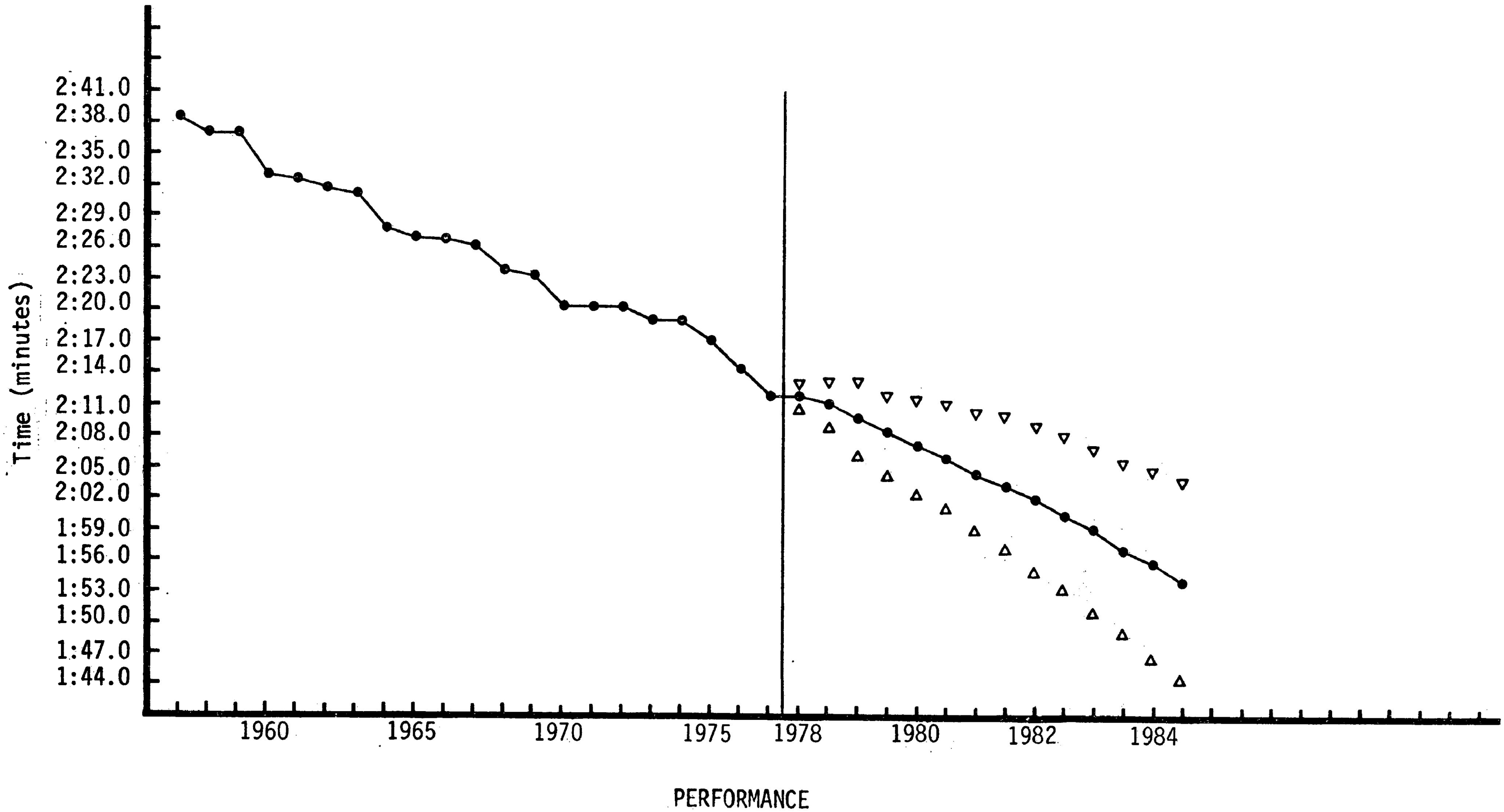


PERFORMANCE

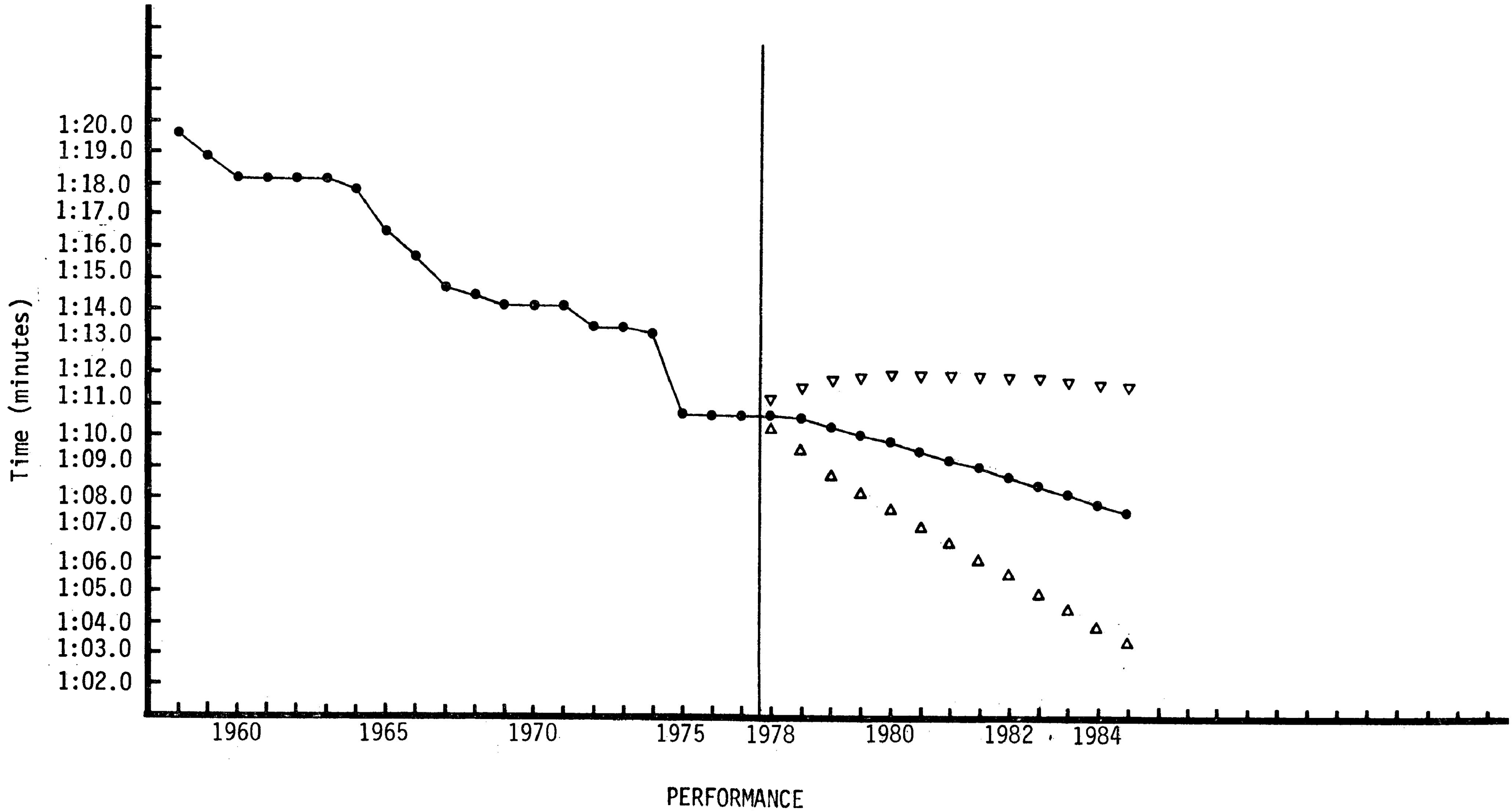
Women's 200 Metre Butterfly



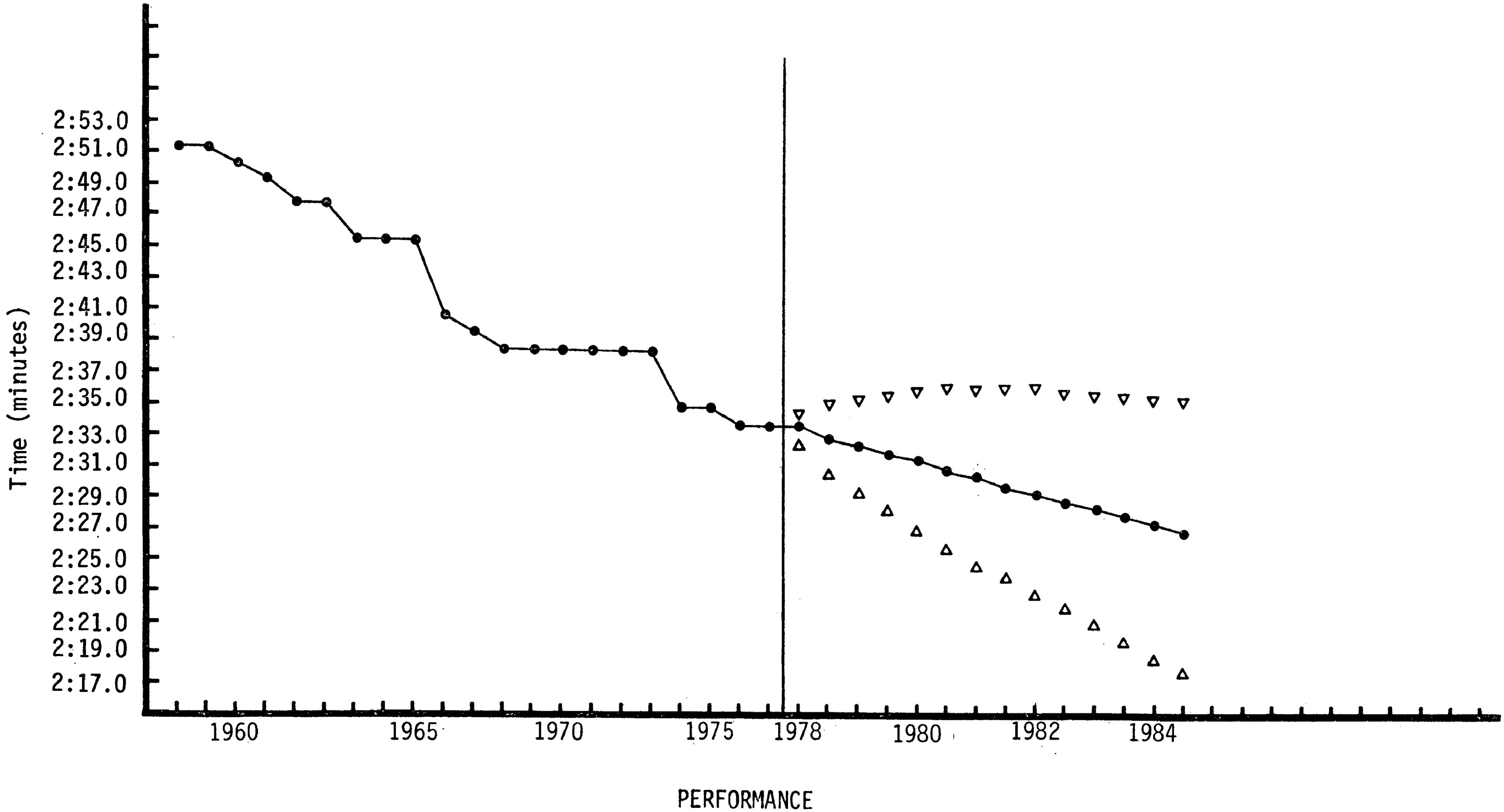
Women's 100 Metre Back-stroke



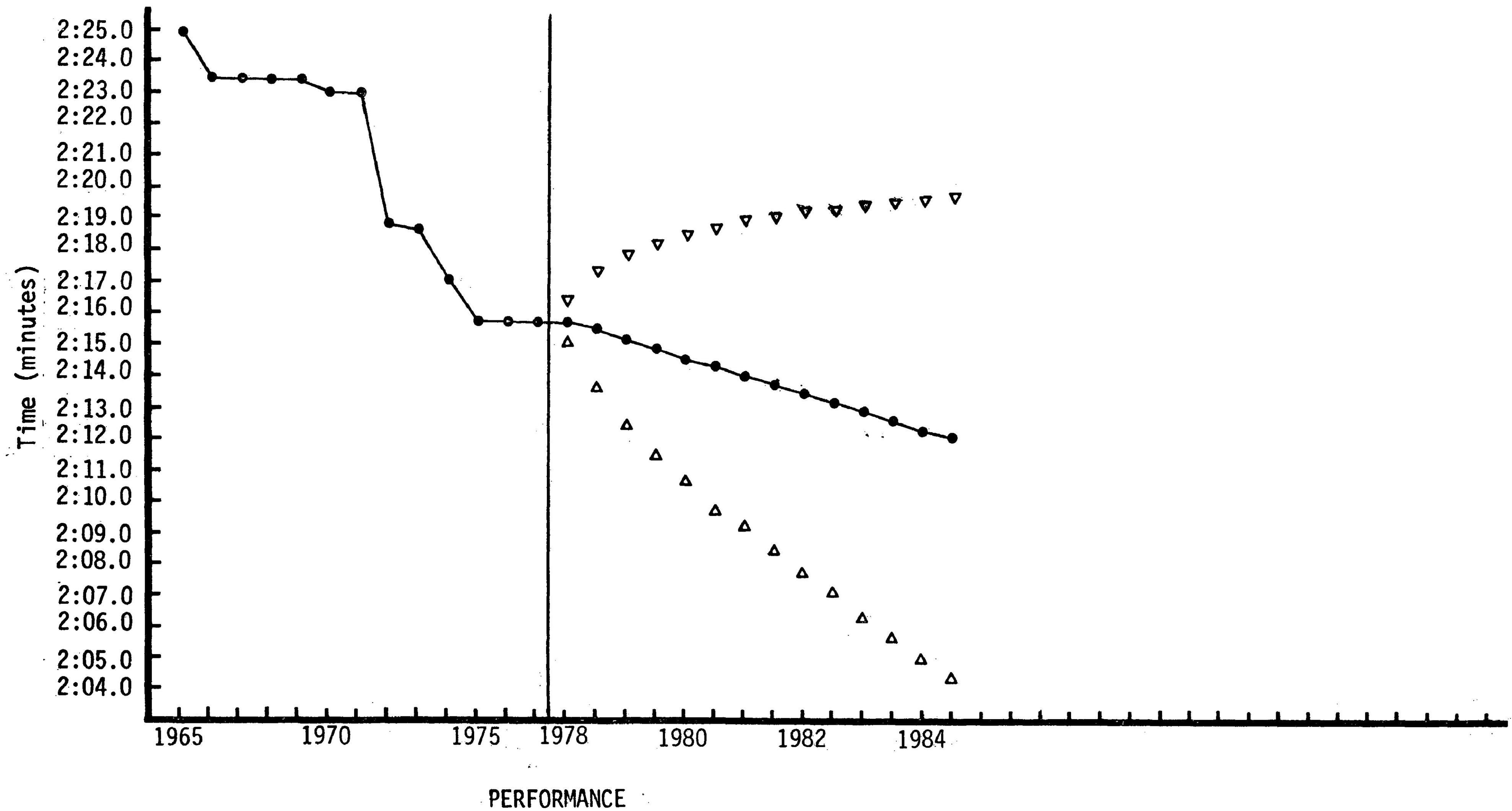
Women's 200 Metre Back-stroke



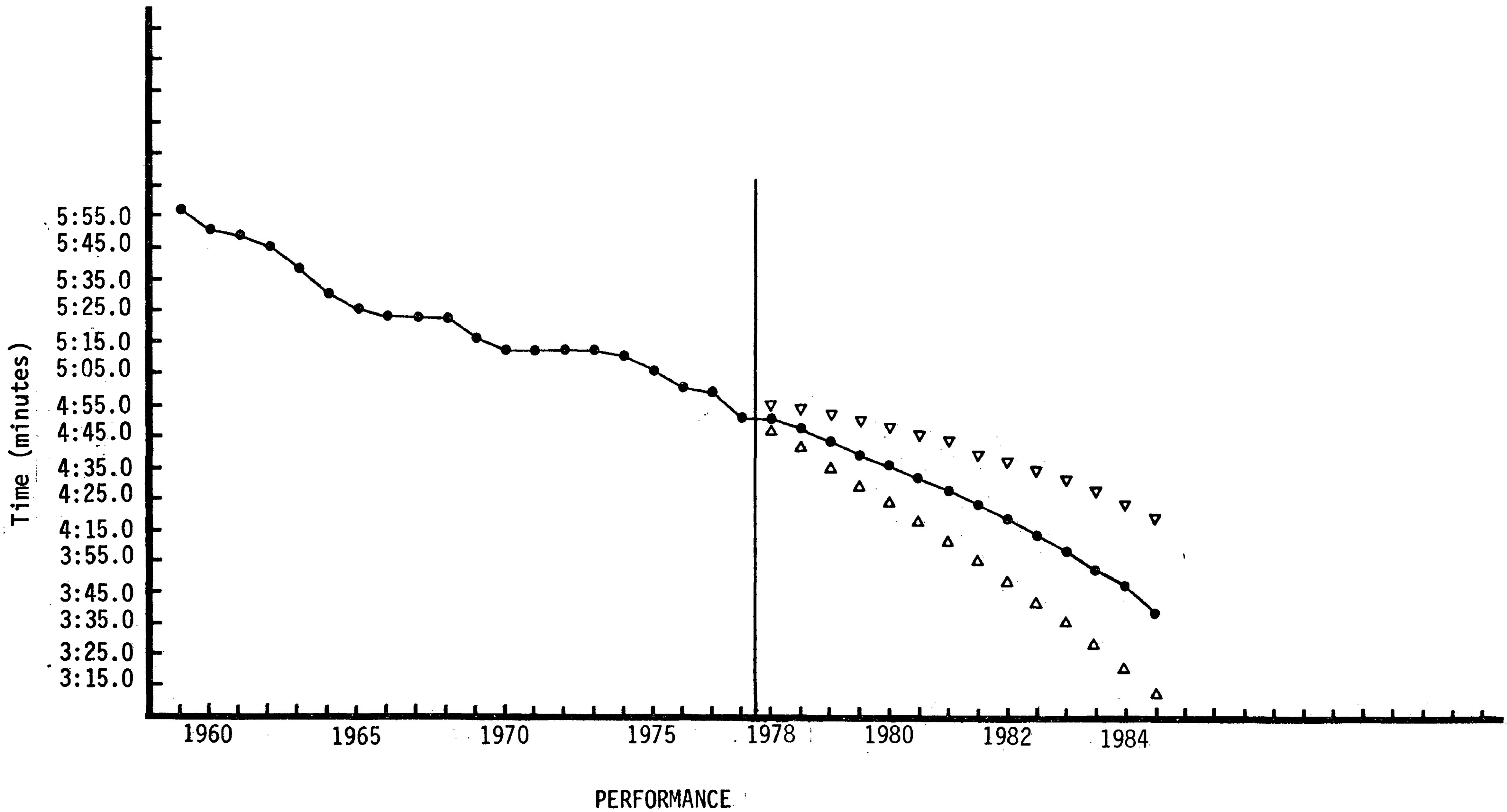
Women's 100 Metre Breast-stroke



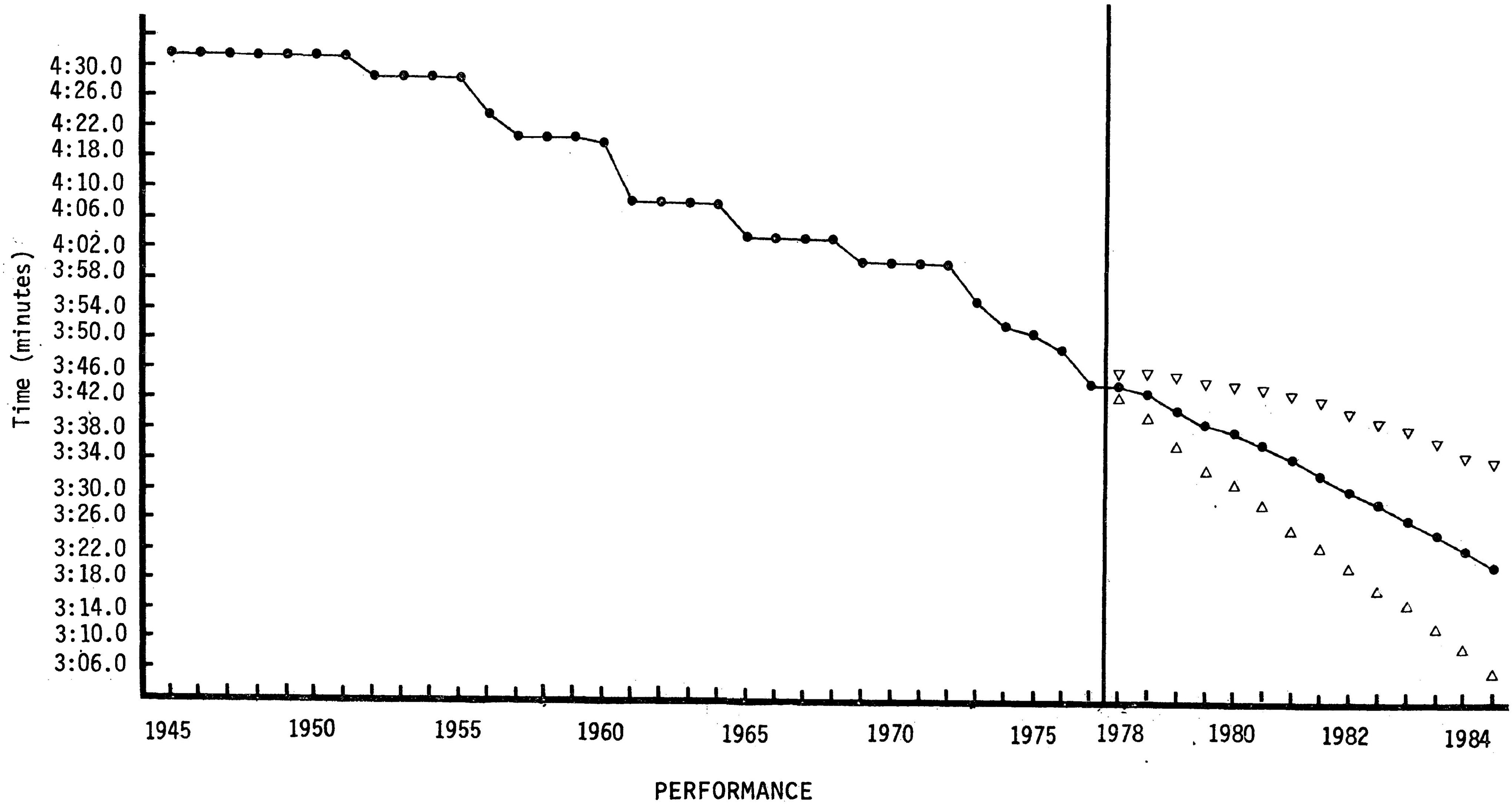
Women's 200 Metre Breast-stroke



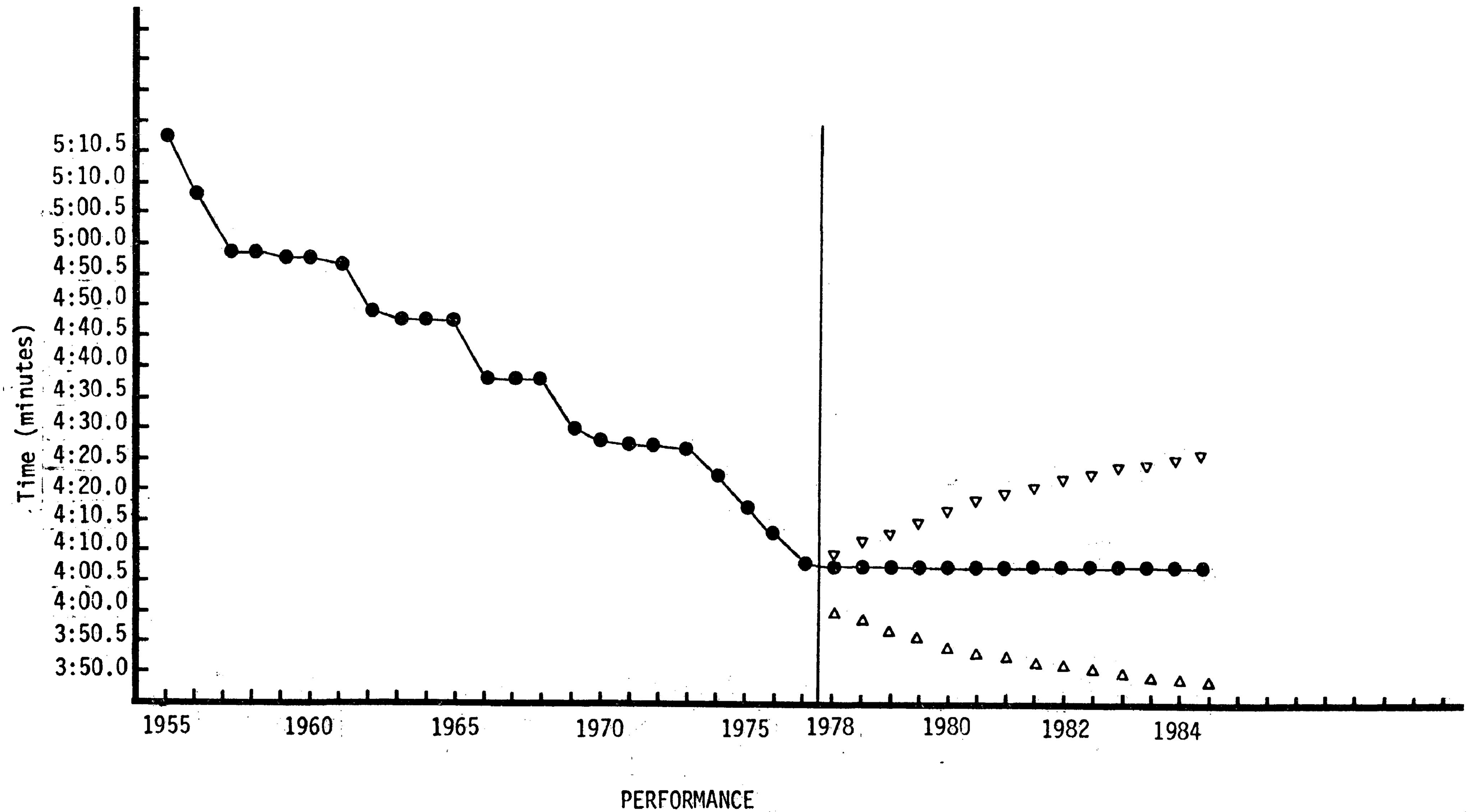
Women's 200 Metre Individual Medley



Women's 400 Metre Individual Medley



Women's 4 X 100 Metre Free Relay



Women's 4 X 100 Metre Medley Relay