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REVIEW PAPER

Computers in Some Branches of Applied Physiology

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ABSTRACT

This paper reviews the applications of computers in the evaluation of different types of problems occurring in some branches of applied physiology. The recent applications of computers to perform advanced multivariate regression analysis for developing regression models in applied physiology are also highlighted. The regression models are of practical significance for screening personnel in defence services, mines, industrial works, sports and the like.

1. INTRODUCTION

With the advancement of new theories relating to biological systems, it has become impossible to describe certain biological phenomena by elementary mathematical/statistical techniques. The complex mathematical/statistical procedures to interpret such intricate phenomena require the facility of computer techniques. Frome and Frederickson[1] suggested the application of spectrum analysis to describe phonography. They proposed separate spectra for the first and second heart sounds. The application of spectra was also shown in both experimental and clinical investigations. The method proposed by them had applications in both the diagnosis of cardiovascular diseases and monitoring of critically ill patients. Recent developments in biomedical measurements, analog-to-digital converters and high-speed digital computers have led to a new kind of problem in data analysis. Digital spectrum analysis has also been applied to many problems that involve physiological data: electro-encephalography[2,3] and respiratory problems[4].

The problem of selection of best variables from a large number of predicting ones has been of great interest to applied statisticians and with the increasing availability of high-speed electronic computers, the problem has received much attention in the recent statistical literature. Hocking[5] has reviewed various computational techniques and selection criteria with discussion covering the underlying theories in this direction. Krall *et al*[6] have suggested a method which utilizes a stepwise procedure for choosing important variables associated with multiple myeloma survival data and have examined 16 concomitant variables for their possible relationship with survival time. Out of 16 variables, only three were chosen to predict survival time. Studies of multivariate analysis to screen out the risk factors of coronary heart disease[7-10] have also revealed the necessity of computers in medical diagnosis. Recently Bandopadhyay *et al*[11] have used computers to predict peak expiratory flow rate from physical characteristics in young healthy Indian girls. They demonstrated the application of computers for the development of an appropriate multiple linear regression equation for predicting peak expiratory flow rate. Computers have also played a major role in the construction of various regression equations for indirect estimation of human energy expenditure, maximal aerobic power, human endurance time under various environmental conditions, ventilatory 'norms', body composition determinants, etc. at high altitudes from simple concomitant variables. These responses have been considered as the direct measure of physical work capacity, human endurance fitness and certain lung diseases, etc. The indirect estimation of these responses from regression equations will serve well as the screening procedure for selecting appropriate personnel to various defence services. This paper reviews the role of computers in the physiological research for solving important problems in some branches of applied physiology.

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2. EXERCISE PHYSIOLOGY

With the advancement of computer techniques and increasing availability of electronic computers, it has been possible to perform complex multivariate regression analysis of physiological data pertaining to exercise physiology for the development of linear and nonlinear regression models to predict certain physiological responses from simple concomitant variables.

Verma *et al*[12] made use of computer techniques to perform stepwise linear regression analysis for estimating maximal aerobic power from anthropometric measurements. Twenty-seven anthropometric variables were examined for their possible relationship to maximal aerobic power. Four of these variables, namely stature, weight, elbow width and juxta-nipple skinfold thickness, accounted for 34.9 per cent of the variation in maximal aerobic power. The equation constructed for predicting maximal aerobic power from these four variables had a multiple correlation coefficient of 0.591 ($P<0.001$). Computer techniques have also played an important role in predicting maximal aerobic power from body weight, time for 3.2 km run and exercise dyspnoeic index[13]. The predictors have been selected by examining the product moment correlations of body weight, relative body weight indices, time for 3.2 km run, chest expansion, height and exercise dyspnoeic index with maximal aerobic power based on the data collected on 320 healthy Indian males (17-22 years). It was observed that body weight, time for 3.2 km run and exercise dyspnoeic index attained maximum correlations with maximal aerobic power. Thus, two regression equations with two and three independent variables were established to predict maximal aerobic power. The first regression equation yielded a multiple correlation of 0.608 ($P<0.001$) with a standard error of 0.214 $l.min^{-1}$. In this equation body weight and time for 3.2 km run were considered as significant predictors. To increase the precision of this equation, another multiple linear regression equation based on body weight, time for 3.2 km run and exercise dyspnoeic index as predictors was developed. This equation yielded a multiple correlation of 0.658 ($P<0.001$) with a standard error of 0.204 $l\ min^{-1}$. Hermiston and Faulkner[14] used a stepwise linear regression technique to develop suitable multiple linear regression models for prediction of maximal oxygen uptake of physically active as well as physically inactive men using an electronic computer. The most accurate prediction for physically active men was obtained from a regression model which included the subject's age, fat-free weight, HR, fraction of carbon dioxide in expired gas and tidal volume at a submaximal work level, in addition to the rate of change of the respiratory exchange ratio. For physically inactive men, the most accurate prediction model included age, fat-free weight, respiratory exchange ratio and tidal volume at a submaximal work level.

Verma *et al*[15] performed multivariate regression analysis for indirect assessment of energy expenditure at different work rates. They established a multiple linear regression equation for indirect estimation of energy expenditure from minute ventilation and heart rate during exercise on a bicycle ergometer. Keeping in view a strong relationship of energy expenditure with minute ventilation and heart rate, these workers constructed a nomogram to predict energy expenditure from these concomitant variables. This nomogram is very useful in practice for biomedical scientists who are not well acquainted with the mathematical/statistical calculations involved in the multiple linear regression equation.

Dimri and Verma[16] used computer techniques for performing a stepwise linear regression analysis to examine the possible relationship of various physiological and environmental variables with endurance time. They suggested multiple linear regression equations for predicting endurance time from sweat rate, work load, oxford index, skin temperature, and relative work load during continuous work in heat The first regression equation consists of sweat rate, work load, oxford index and skin temperature as predictors for estimating human endurance time with a multiple correlation of 0.837. The second regression equation was constructed with the three variables (viz. relative work load, sweat rate and oxford index) as predictors with a multiple correlation of 0.876 between the observed and estimated endurance times. Assuming mechanical efficiency as found during submaximal cycling Ingen-Schenau *et al*[17] have developed, a model in the form of differential equation to predict realistic times at 100,200 and 400 m distances by solving the differential equation through computer simulation. Recently, Moroz and Tikhonov[18] used the computer for predicting the working capacity of operators by multivariate statistical analysis.

3. RESPIRATORY PHYSIOLOGY

With the increasing availability of electronic computers, it has become possible to develop various regression equations for predicting important ventilatory 'norms' using the simplest concomitant variables. Verma *et al*[19] developed various regression equations for predicting ventilatory 'norms' using age, height and weight as predictors for a wide age range (21-69 years) with the help of computers. These regression equations were developed for predicting vital capacity, forced vital capacity, forced expiratory volume for one second, expiratory reserve volume, inspiratory capacity and maximum voluntary ventilation. The coefficients of determination (R^2) of these regression equations ranged from 26.41 to 54.92 per cent depending on the variables selected for prediction. Problems of mathematical analysis of a respiratory control system have been dealt with by Grodins *et al*[20]. They evaluated a set of differential equations which were solved by making use of advanced computer techniques. Later, Duffin[21] proposed a mathematical model for the chemoreflex control of ventilation and worked out the chemoreflex equations which were linked to a simple mathematical model of the respiratory process, consisting of a single alveolus and a tissue storage compartment, to form a model of the respiratory control system. The resulting set of nonlinear, first-order differential equations was solved by simulation on an analog computer. The chemoreflex equations approximated the exact mathematical description of the chemoreflex control of ventilation. Nunn and Grey[22] used the computer to develop a regression model for predicting peak expiratory flow (PEF) rate from age and height in men and women. With this model, predicted values could be derived for men and women aged between 15 and 85 years. The new regression equations for PEF enable one to predict values for people aged 15-85 years and so enhance the accuracy of testing in the elderly. Recently, Bandopadhyay *et al*[11] used the computer to perform multivariate regression analysis for developing regression equation to predict peak expiratory flow rate from physical characteristics. Age and height were significant predictors of peak expiratory flow rate. The regression equation yielded a multiple correlation of 0.870 with a standard error of 39.9 l min^{-1}. In view of such a good agreement between the observed and estimated values of peak expiratory flow rate, a nomogram was also constructed for its indirect estimation from age and height. The nomogram is very useful for biomedical scientists who are not well acquainted with the statistical calculations involved in the multiple linear regression equation.

4. PHYSIOLOGICAL ANTHROPOMETRY

The problem of variable selection from a large number of variables to predict certain important dependent variables has been of interest to both applied statisticians and anthropologists working in applied physiology. For this purpose, various statistical techniques have been developed and the techniques have been used by several workers using electronic computers in the field of physiological anthropometry. Bharadwaj *et al*[23] performed a stepwise linear regression analysis using computers for examining the possible relationship of 36 body measurements with body density and lean body weight. Only four measurements (viz anterior thigh and juxta nipple skinfold thicknesses and forearm and ankle circumferences) were selected out of 36 measurements in the regression equation predicting body density. A multiple correlation coefficient (R) of 0.765 was obtained for this equation. For the predicted lean body weight, R was 0.930. Four body measurements (viz body weight, anterior thigh and juxta nipple skinfold thicknesses, and forearm circumference) were selected out of 36 measurements to develop a multiple linear regression equation for predicting lean body weight.

Verma *et al*[24] made use of a stepwise linear regression technique using a high-speed electronic computer for selecting predictor variables associated with the total body volume. Only four body measurements (viz body weight, anterior thigh, suprailiac and subscapular skinfold thicknesses) were selected out of 35 measurements for predicting total body volume. A multiple correlation coefficient of 0.9987 was obtained for the multiple linear regression equation constructed on these four antropometric measurements. Excluding body weight from the list of predictor variables, the stepwise linear regression analysis was again performed to examine the possible relationship of 34 variables with total body volume. Nine variables (viz. height, shoulder, thigh, calf, neck, abdomen I, abdomen II, buttock and forearm circumferences) were selected to predict total body volume. The equation thus obtained from nine variables accounted for a multiple correlation coefficient of 0.9854. Bharadwaj *et al*[25] used computer techniques to develop simple multiple linear regression equation for predicting fat free mass from stature and x-ray muscle widths at thigh and calf regions in Indian males. This regression equation yielded a multiple correlation of 0.80 ($P<0.001$) with a standard error of 2.79 kg. Recently, Bharadwaj *et al*[26] used the computer to perform a stepwise linear regression analysis for predicting the clothing measurements from body measurements. These regression equations were used to work out the dimensions of trousers and shirts for different sizes from the classified anthropometric data.

5. SUMMARY

The problem of variable selection from a large number of concomitant variables has been of practical significance to both applied statisticians and biomedical scientists. These problems cannot be handled with a desk calculator and need high-speed computers. With the advancement of computer technology, it has become possible to make use of the latest statistical techniques to develop various models for predicting physiological responses pertaining to various branches of applied physiology. Bharadwaj *et al*[23] used the electronic computer to perform a stepwise linear regression analysis for establishing the multiple linear regression equations to predict body density and lean body weight from important body measurements at high altitudes. The necessity to establish these equations was realized owing to the nonavailability of the equations for Indian subjects at high altitude situations. Similarly, Verma *et al*[12] developed multiple linear regression equations for assessment of maximal aerobic power from body measurements by performing a stepwise linear regression analysis on the electronic computer. These equations are of practical utility in screening a large number of subjects for selection of personnel required for certain military and industrial tasks. Age and height were considered as predictors after performing multivariate regression analysis of peak expiratory flow rate in Indian girls[11].

Computer simulation techniques have played an important role in the mathematical analysis of the respiratory system[20,21]. The use of computers has therefore become indispensable in the field of applied physiology.

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