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ABSTRACT

Research statistics has established the fact that physical work capacity declines as a consequence of aging. The question has been raised, however, if this decline is the inevitable result of senescence or merely due to changes in living habits. Great numbers of people have been observed not to comply with the statistics. One is inclined to explain such exceptions from the rule on the basis of extraordinary biological characteristics, but the real reason might be a more adequate balance of essential factors in daily life such as work, rest, tension, play, nutrition, physical activity, and others. As maximum performance capacity is only developed and maintained through hard training, the preservation of an "acceptable" level of work capacity requires frequent exposures to sufficiently high functional demands. Within this concept, two situations under experimental scrutiny are of interest: first, physiological parameters, indicative for physical performance capacity, were intra-individually measured over the years whereby changes of work capacity became apparent as consequence of training, environment, inactivity, disease and retraining. The latter restored the functional adaptability at age 56 nearly to that observed at age 20-30. In the second situation, an individual (age 53) with essential hypertension, a disease considered to be associated with aging processes of the vascular tissue, has been studied over months with results encouraging the application of an individually devised program of regular activities for the mitigation of such disease.

INTRODUCTION

Common knowledge points to the fact that advancing age is associated with a decrease of man's capacity for strenuous physical efforts. Experimental studies, confirming such general observation, were critically reviewed by Norris and Shock in 1960.[1] These authors, however, mentioned the need for more physiological experimentation on older people who had preserved high performance capacity levels through regular physical training. Jokl,[2] in 1954, evaluated performance data of more than a thousand 50 to 80 year old men competing in gymnastics and track events, and concluded that continuous physical training appeared to be the most efficient antidote against physiological aging. Carl Diem,[3] in a fine lecture on "Sport and Age," in 1957, cited numerous examples of elderly individuals with extremely well preserved performance capabilities. Mateeff[4] pointed out the importance of physical exercise upon cerebral activity and emphasized the correct combination of mental and physical activities for preserving a high functioning capacity of the brain cells.

There are two ways of conducting an inquiry into the effects of age, namely, the statistical study of different age groups, and the study of individuals as they progress from decade to decade. This was pointed out in 1945 by Dawson[5] who adopted the second way and now, at age 90, has accumulated a large set of performance data on himself.

A classical group study on "physical fitness in relation to age" was done by Sid Robinson,[6]

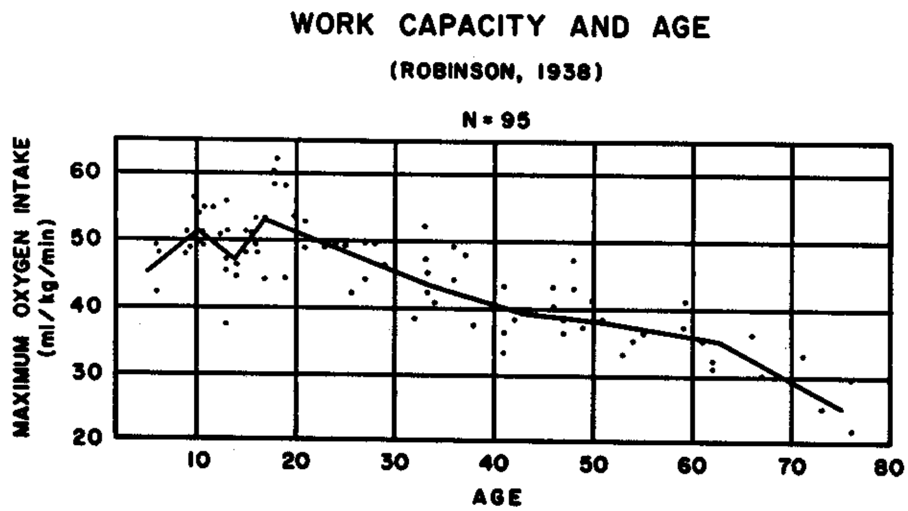

FIGURE 1. Work Capacity and Age (Robinson, 1938).

and reported in 1938. The first illustration (Fig. 1) summarizes his findings on 95 male subjects. Utilizing the maximum attainable oxygen intake per unit of body mass as the physiologically most meaningful index of physical fitness, he demonstrated that work capacity had its peak at age twenty, then declined to 79 per cent of this peak at age forty, to 67 per cent at age sixty, and became reduced to less than 50 per cent toward the age of eighty. A similar trend of age-depending loss of work capacity was reported by Hollmann and Knipping in 1960.[7]

The experimental results of more recent investigations[8] on large groups of the male population in the U.S.A. deviate considerably from Robinson's data. (See Fig. 2). Apparently, the average fitness level now is much lower than it was in 1938. An attempt was made to separate "normal individuals" (represented by solid dots) from those who had been in programs of regular physical exercise for at least twelve weeks (open circles). Only such individuals were considered "regularly physical active" who had three or more weekly exercise periods in which at least 350-500 kcal of energy

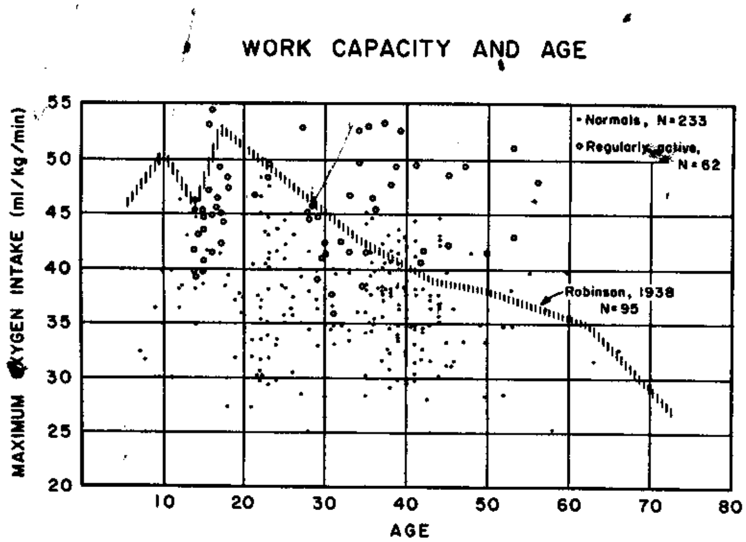

FIGURE 2. Work Capacity and Age.

were expended within 30 minutes of actual work. It appears evident that the physical working capacity of regularly active people does not follow the age related trend of deterioration as seen in the "normals." In subjects up to 57 years of age, a sufficient period of physical training elevated the working capacity considerably above the slumping line of averages. It should be mentioned that a peak oxygen intake of 35-40 ml/kg/min, equivalent to an energy expenditure of 10-11 times the basal metabolic rate, represents an "average" level of physical fitness while values above 40 ml/kg indicate superior, values below 35 ml/kg inferior levels of work capacity.

The individual approach of studying age-related physiological changes over the years was used by Dill[9] with himself as an experimental subject. This exceedingly active investigator of environmental and exercise stresses has never really attempted to attain or to maintain maximum levels of functional capacity. Experimental data of his peak oxygen intake and maximum heart rate over a period of 35 years, from age 36 to 71 are shown on Fig. 3. The dashed line, indicating his performance drop-off over the years, approximates closely the average curve established by Robinson.

The solid line, in contrast, represents performance data of a subject who made special efforts to regain the highest possible level of work capacity after unavoidable fitness slumps due to detrimental living conditions, accidents or diseases. Evidently, sufficiently long periods of inactivity caused a reduction of physical working capacity toward the average level observed in the "normal" population. The return to peak levels of performance capacity was depending on the type, the intensity and on the frequency of regular physical exercise.

An age-related decrease of maximum heart rate during physical efforts has been reported by several authors.[10,11] The results on Dill underscore these observations convincingly. But here again, for the individual staying physiologically younger through physical training, there might be exceptions to the general rule. In Balke's case, the relatively low values observed after passing the age 50 appeared to have been caused by extreme training efforts. This was concluded from experimental results of two young cross-country runners who after hard training, did not exceed 168, respectively 172 beats per minute during maximum effort. The fact that such reduction in maximum pulse frequency must not be considered an indication

MAXIMUM HEART RATE AND OXYGEN INTAKE VERSUS AGE

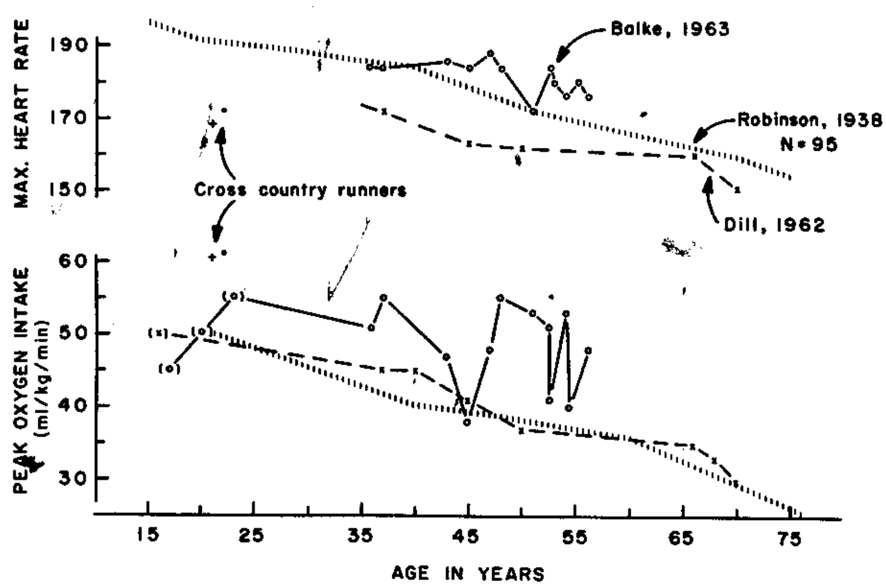

FIGURE 3. Maximum Heart Rate and Oxygen Intake Versus Age.

MAXIMUM CARDIAC OUTPUT VERSUS AGE

SUBJECT	AGE YEARS	WEIGHT kg	MAX V_{O_2} l/min	C.O. l/min	MAXIMUM HEART RATE
Ph.	23	79	3.79	32.0	172
Pa.	26	81	3.44	33.2	180
Fi.	27	78	4.03	31.1	168
Na.	28	79	3.48	34.0	180
Ba.	53	76	3.63	33.6	172

Subjects run regularly 3-6 km three times a week.

TABLE I.

of faltering cardiac capacity is illustrated in Table 1: of five regularly active subjects, four being in their twenties and one above fifty, all having nearly the same body weight and superior functional adaptive capacities, similar cardiac outputs were found during maximum physical efforts despite slight differences in maximum heart rates.

Another evidence for the potential value of regular physical exercise in reversing the process of physiological aging is presented in the following: a man, age 53, slightly overweight, holding a job which frequently involves great mental and psychological strain and tension (air traffic control), contacted us for advice concerning a steadily increasing blood pressure. Despite medical treatment the hypertension had progressed during the last 3 years (see Fig. 4). Presently, in a state of complete relaxation, the readings were 184 over 111 mm Hg.

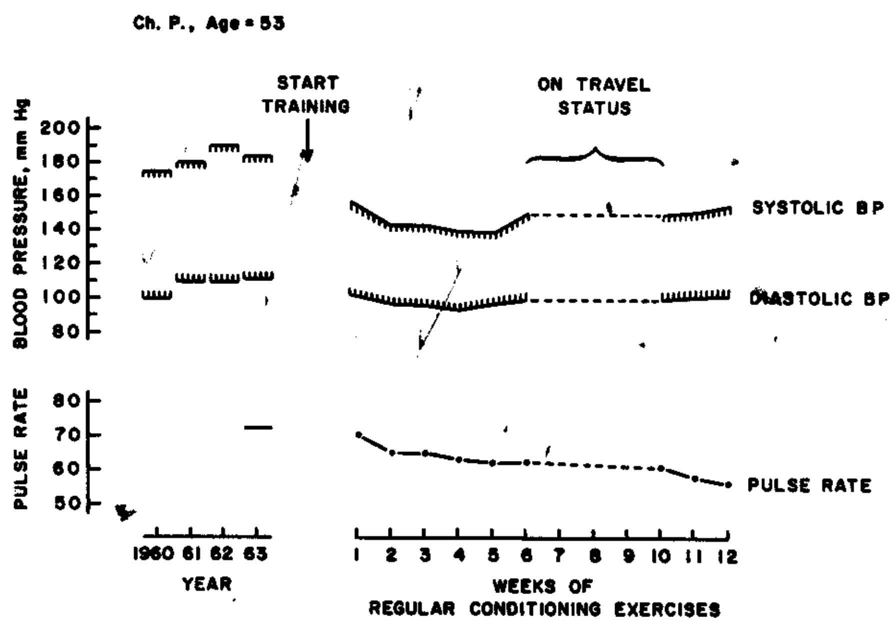

FIGURE 4. Blood pressure and heart rate before and during a program of regular physical exercise.

After several control tests had been performed, this individual was subjected to a regular program of physical exercises because it had been observed on several occasions that slightly hypertensive people had become temporarily normotensive after good physical work-outs. The training was begun with carefully monitored interval work on the bicycle ergometer and treadmill and progressed to ball games, rope jumping and out-door running. The plot of his average daily resting blood pressures and pulse rates for each week following the beginning of training indicates an activation of physiological mechanisms normalizing the cardiovascular tonus. Even under great psychological pressure, as during the 6th week of training filled with examinations, and during the 10th-12th week of a heavy schedule as an instructor in class work, the pre-exercise resting blood pressure never came near the originally observed values. Post-exercise blood pressures, measured approximately 15 minutes after cessation of the daily exercise, were usually 10-20 mm Hg lower than the pre-exercise values.

The twelve weeks of regular training did not only result in a considerable normalization of blood pressure but also in a remarkable 25 per cent increase of work capacity, as Fig. 5 demonstrates. Before training, definite cardiorespiratory limitations occurred, in our standardized fitness test on the treadmill, at an energy demand of close to 10 times the basal metabolic rate but after training at demands of 12.5 Mets. The lower pulse pressure and pulse rates, not only during rest but also at any comparable work load, were indicative of greater economy and less strain on part of the systems involved in the blood transport. Physiologically, these results had to be considered a rejuvenescence of essential organic functions.

Summarizing, then, it can be said that physical activity of adequate quality and quantity modifies the pace and the intensity of physiological aging. Experimental observations on many more people who will volunteer to strive for optimum fitness throughout their life time are desperately needed.

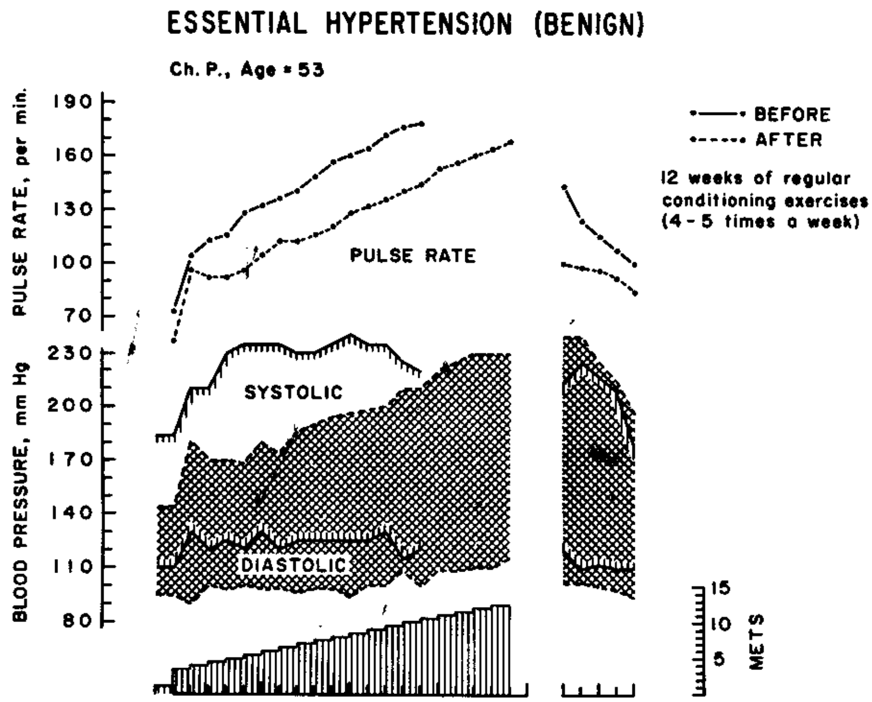

FIGURE 5. Cardiovascular response to gradually increasing work before and after physical conditioning.

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