The Biomechanical Foundations of a Safe Labor Environment: Bernstein’s Vision in 1930

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Mechanical interaction between a human and the environment at work are not always safe and comfortable. In certain conditions, a sub-optimal environment may cause discomfort, reduced productivity, or even work-related diseases. While several factors may lead to low efficacy of the system “man-machine-environment,” the lack of information on the mechanical properties of the human body affects the design of equipment, manufacturing tools, and even household goods.

For centuries, humans have created and improved their working environment. There are references to cases of tool adjustment to anatomo-physiological parameters of the human body dating back to the XV century (Gorshkov, 1979). However, because of the lack of scientific information on the biomechanical parameters of the human body at that time, the only way to optimize the design of a hammer or a chair was based on experience and intuition. In many cases, it was successful: The modified tools, household goods, and footwear were associated with increased productivity and contributed to a more comfortable life.

The technical revolution of the 19th century was associated with intensified physical labor. The lack of concern before and slightly after the turn of the century for worker injuries induced by their mechanical interaction with tools was based on economics. The labor was cheap and an injured worker could easily be replaced. This insensitivity to problems of exposure of the workforce to work-related disease lasted until World War I, when the labor force became an essential resource for the survival of warring nations. In addition, much of the biomechanical information available prior to World War I was empirical, descriptive, and unreliable. This situation continued until the discipline of ergonomics was born.

The science of ergonomics, or human factors, as it is also known in North America, is a little more than 40 years old. It was founded by a group of British scientists including anatomists, physiologists, psychologists, and engineers, who had been working for the armed services and dealt with the efficacy of the fighting man. Like Bernstein, they believed that a multidisciplinary scientific approach to the study of working efficacy could be equally relevant to any industry. In its present form, ergonomics dates back to World War II and the years immediately following it. However, ergonomics has at least several distinct roots to the early
1900s. Among the factors that helped shape the field of ergonomics, one can mention the classic work by the Industrial Fatigue Research Board in the United Kingdom between World Wars I and II that contributed greatly to our understanding of environmental effects on human work performance, as well as the development of "scientific management" by Frederick W. Taylor and "industrial psychology" by Hugo Munsterberg (Hendrick, 1999). In this list of contributors to the development of the scientific foundation for a safe working environment, one should mention the contribution of the Russian school and its valuable contribution in psychology, mathematics, engineering, and human movement science. Associated with the last of these is N.A. Bernstein, whose scientific contribution has become highly recognized after his death.

While I was too young to know N.A. Berstein personally, I was lucky enough to interact with his former graduate students, associates, and followers. Bernstein's spirit influenced the scientific lives of many Russian scientists including myself. Later, when the waves of scientific recognition reached the West (Bernstein, 1967), Bernstein's name became known and associated with the thoughtful integration of scientific knowledge about human movement and theories and principles that still attract the interest of the scientific community on both sides of the Atlantic, such as the principle of hierarchical control, the principle of sensory corrections, and the formulation of the problem of motor redundancy. In the former USSR, research aspects of the biomechanics of labor were overseen by the section on labor and sport biomechanics (of which I was the scientific coordinator) of the Scientific Council for Biomechanics created in 1975 at the USSR Academy of Sciences.

The paper "Contemporary Biomechanics and Problems of Labor Safety" was published in the journal *Hygiene, Safety, and Pathology of Labor* in 1930. It consists of two parts. First, there is a report (Bernstein called it a review) of what had been done since his Laboratory of Biomechanics of Labor was organized and why it was important to study human movement in relation to the problem of labor safety. The second part is a description of several methods developed by Bernstein and his coworkers that allowed his laboratory "to move directly to studying the problem of interaction between movements of the machine and of the worker that were discussed in the first part of the paper."

At that time, the political situation in the former USSR was tough. The economy was in disarray, and the entire country was involved in the process of improving industrial production. Numerous worker initiatives (e.g., digging 300% of the daily norm of coal, working on five fabric manufacturing machines instead of one) were introduced and supported by the political leaders. Such workers were declared heroes. In particular, a miner named Stakhanov inspired thousands of followers and made a significant impact on the increase in mineral mining production. It was a battle for the future strength and prosperity of the country. And, as occurs in almost every battle, there were casualties, injuries, and disabilities related to overwork, sub-optimal working conditions, and extra-heavy physical work. It would be wrong to say that the government was careless about worker health. Institutions, laboratories, and departments of labor safety were in charge of improving working conditions. However, this goal was secondary to increased productivity.

The goal of the paper that Bernstein wrote in 1930 was two-fold. It seems to me that he wanted to attract the attention of the scientific community to a new direction of studies while simultaneously seeking official "approval" to use
biomechanics to increase worker efficiency while avoiding injuries. The former goal was very important in his work for a state institute, where scientists were assigned research tasks aimed at improving the labor safety. Bernstein succeeded in achieving both goals. In particular, his laboratory continued to receive support, which allowed his group to survive and continue performing their unique studies. It is important to mention that involvement in practical research served to shelter them and maintain relative political neutrality. Such political neutrality allowed Bernstein to survive and even get official recognition in 1947, when he was awarded the Stalin prize. Soon after, and despite his political caution, Bernstein was fired and restricted from his laboratory (Feigenberg & Latash, 1996).

In the 1920s, Bernstein began a new direction of studies related to labor safety. In fact, and the paper demonstrates this clearly, it was the first attempt to integrate scientific knowledge on the mechanical interaction of hu³ans with mechanical devices. Bernstein and his group published a series of experimental papers that demonstrated the importance of biomechanics in improving working conditions.

During the last two decades, research on biomechanical aspects of ergonomics, human factors, and labor safety intensified significantly in both the former USSR and worldwide. In the former USSR, five All-Union Conferences on Ergonomic Biomechanics were organized from 1986–1990 (see, e.g., Aruin & Prilutsky, 1988; Mirtov & Aruin, 1988), and the first monograph on the biomechanical aspects of ergonomics (Aruin & Zatsiorsky, 1989) was published in Russia since Bernstein introduced the need for biomechanical data for optimization of the labor environment. Several important, comprehensive books related to the optimization of various labor movements and the development of tools based on biomechanical principles were published in the U.S. Among them were Biomechanical Basis of Ergonomics by Tichauer (1978), Occupational Biomechanics by Chaffin, Anderson, and Martin (1999), and Biomechanics in Ergonomics by Kumar (1999).

The scientific vision of N.A. Bernstein helped to create and shape the field of biomechanics, especially as it related to labor safety. Presently, occupational biomechanics, a discipline that helps to create an optimal working environment, is growing and undoubtedly has great potential. N.A. Bernstein started this field; we should pay tribute to his scientific intuition.

**Contemporary Biomechanics and Problems of Labor Safety¹**

*N.A. Bernstein*

I. Less than one year has passed since the opening of the Laboratory of Labor Biophysics at the State Institute of Labor Safety.² The Laboratory has primarily focused its attention on issues of biomechanics. Despite the short time period, it can already be stated that the number and diversity of the points of common interest between the Laboratory and the field of Labor Safety are very large.³ Life