

FOOTWEAR RESEARCH - PAST, PRESENT AND FUTURE

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A review and preview of footwear research allows us to step back for a short time to critically review our own field of research from a distance. This review is divided into three sections, the past, the present and the future. While one could go back into the centuries, this paper is limited to the recent past between 1970 and 1995. The present has been defined as the last 10 years. The future addresses the work that should be attempted in the next ten years.

Past (1970-1995)

Research on footwear became attractive to movement scientists when the fitness and running activities started to boom in the early 1970's^{4,7,13,15,17,21,31}. Initial work concentrated on the kinematic analysis of the foot and the lower extremities^{6,31}, on external and internal forces^{2,3,5,10,12,29,38}, energy aspects of running shoes^{14,40,45} and on the relationship between biomechanical variables and injuries^{8,11,15,16,17,20,23,33,34,36,37}. These studies established variables such as rearfoot motion³¹, in-eversion, tibial rotation and impact¹² and active³¹ ground reaction forces. Most of the work was done on running, leading to the concepts of cushioning, rearfoot-control and guidance. It was suggested that running shoes (and for that matter most sport shoes in general) should be built to reduce impact loading and to control (≈reduce) foot eversion and guide take-off inversion. It was suggested that these functions would reduce movement related injuries⁴. Tests were developed and used by running magazines to rank running shoes, quantifying cushioning, rearfoot stability and other variables⁴.

Results of this research and testing were partly responsible for sport shoes that were developed into relatively bulky constructions with rigid heel counters, stiff heel stabilizers and wide lateral heel wedges, which may have been responsible for new problems and injuries. The wide lateral wedges, for instance, produced increased levers and were responsible for an increase in foot/shoe eversion²⁹, which was counteracted with stiffening of the medial shoe construction.

Positive outcomes of this initial phase:

- The actual research questions were developed.
- Methodologies to quantify kinematic and kinetic variables were developed.

Negative outcomes of this initial phase:

- The initial approach was purely mechanical (no sensory feedback or biological reactions) and descriptive.
- Initial results were often over-interpreted and were partly responsible for a few “blunders” in sport shoe construction.

Present (1995-2005)

During the last ten years, research on footwear made substantial progress. The findings of some initial studies (certain results were not as expected) initiated more studies addressing often more realistic problems^{9,19,22,26,44}. The corresponding results increased the knowledge in footwear research by a quantum leap. Furthermore, old paradigms were challenged and in some cases, new paradigms were proposed and supported by evidence. The most important new proposals and/or findings included:

- (a) Actual skeletal movement and loading as a function of movement tasks and footwear were determined in vitro and, in a few cases, in vivo during walking and running^{1,18,35,39}.
- (b) The connection between sensory and mechanical effects was addressed^{32,36}.
- (c) Barefoot movement was studied and imitated with new shoe constructions³⁹.

- (d) The old paradigm of impact loading and related overloading was challenged and a new paradigm was proposed for impact forces, relating them to soft tissue vibrations and muscle tuning^{27,28,30,41,42,43}.
- (e) The old paradigm for movement control, suggesting that foot eversion/pronation should be minimized was challenged and a new paradigm was proposed, relating joint movement and corresponding muscle activity to a "preferred movement path"³⁰.
- (f) The paradigm of shoe stability was challenged through the construction of unstable shoes with surprising effects related to pain and performance.
- (g) Comfort has been established as an important functional variable of footwear research²⁵.

Positive outcomes of the last ten years of research:

- New technologies were developed to quantify the effects produced by footwear (e.g. pressure distribution²⁴, Wavelet analysis for EMG data⁴³, principal component analysis).
- New paradigms were proposed and some supporting evidence was provided.
- Comfort was established as an important variable.
- New automated robotic testing methodologies were developed.
- Research was performed in academia as well as in the larger footwear companies and the corresponding many results were used by the footwear industry.
- Research has expanded beyond running to include soccer and other sports.
- Energy aspects were studied with respect to performance.

Negative outcomes of the last ten years of research:

- Research was often still descriptive/statistical and functional correlations between biomechanical variables and health or performance related outcome was not available.
- Sport injury development was not addressed by understanding the functional connection between the injuries and the related movement and forces.

Future (2005-2015)

It is impossible to predict the future. However, one can suggest what should be done in the next few years. The major research investments for future projects related to footwear should concentrate on:

(a) Frequency of input signals

Each force acting on the human foot can be described with amplitude and frequency. It has been suggested that the frequency component of this input signal is important³⁰, that it has been neglected in past research and that many performance and injury related questions can be addressed by studying the frequency component of input signals.

(b) Kinematic and Kinetics and injury development

Injury development has often been studied by using statistical correlations between variables²³. It is suggested that the understanding of the development of specific sport injuries will make substantial progress if the studies use functional approaches, connecting local internal forces to overloading and failure of tissue.

(c) Control systems

Forces acting on the musculo-skeletal structure of the human body produce not only mechanical changes but produce changes in the biochemical composition and changes in the sensory feedback^{32,36}. The quantification of those changes (e.g. through functional biological markers) will allow understanding changes in the tissue and/or the movement that may be related to injuries or changes in performance.

(d) Biological adaptation

Every force acting on the human body sends signals to the various tissues. Some of these signals may be responsible for bio-positive or bio-negative effects in structures of the locomotor system. Understanding the effects of such signals and understanding to send the right signals may be a strategy to prevent injuries and/or to improve performance. The knowledge in this

area of research is very limited. However, it may be possible to make substantial and relevant steps in this direction.

(e) Biomechanical shoe-foot models

Footwear research has only rarely used mathematical models to predict behavior of the locomotor system in systematically changed situations. However, this approach would probably provide more insight into loading, performance and injury conditions.

(f) Intelligent footwear

Shoes could/should/will be developed that “understand” the needs of the individual and adapt to those needs.

(f) Performance and footwear

Certain shoe constructions do affect performance positively or negatively. Research should concentrate to identify the reasons for these effects. The understanding of these functional correlations may provide insight into the basics of shoe construction.

Final comment

Footwear research has made substantial progress in the last 30 years. The new methodologies and the bright young researchers joining the field will provide additional substantial and exciting development and progress in the next ten years.

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