MECHANICAL SIMULATION FOR TESTING THE FOREFOOT CUSHIONING OF RUNNING SHOES

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The deformation behaviour of the midsole in the forefoot area of a running shoe receives little attention in current research. To evaluate the influence of a sports equipment such as a running shoe on a performance parameter, it is not sufficient to consider only the mechanical system. To characterize a sports equipment, the sports engineer needs not only the mechanical but also the biomechanical parameters of the sports equipment. To meet these requirements, the sports engineer usually relies on the tool of mechanical simulation, which can be used to analyse and evaluate the interaction between the athlete and the sports equipment in a given context [1]. The objective of this work was to develop a mechanical simulation for testing the forefoot cushioning of running shoes, which can be used to determine the main material properties of the running shoe.

Based on a physical model and considering the relevant literature, a concrete problem was defined. To build the model, it was necessary to analyse the system behaviour between the runner and the running shoe on the basis of biomechanical experiments and to transfer the physical quantities, e.g. measured values for describing the load-time profile during typical sport movements, into constants as input data by means of abstraction. Based on this problem, existing data [2] from a running study (20 male runners, age 26.0 ± 3.2 years, weight 73.8 ± 7.7 kg, height 176.5 ± 4.4 cm) were evaluated with regard to ground reaction forces resulting from forefoot contact in order to determine a representative ground reaction force, whose characteristic values were transferred to a universal testing machine in the form of a load-time profile. The boundary conditions of the indenter to be considered were determined using (i) anthropometric data from the literature (foot length, heel width, and foot width of the 5th percentile of male persons between 18 and 65 years of age taken from DIN 33402 [3]), (ii) data from performed footwear measurements (determination of the space inside the shoe based on seven randomly selected shoes size 8.5 UK), and (iii) plantar pressure data from an existing unpublished study (ten male runners age 28.0 ± 4.7 years, weight 71.9 ± 8.1 kg, height 177.9 ± 3.4 cm) reevaluated according to the intended use. Based on the determined indenter boundary conditions, a physical model of a forefoot, the forefoot indenter, was developed.

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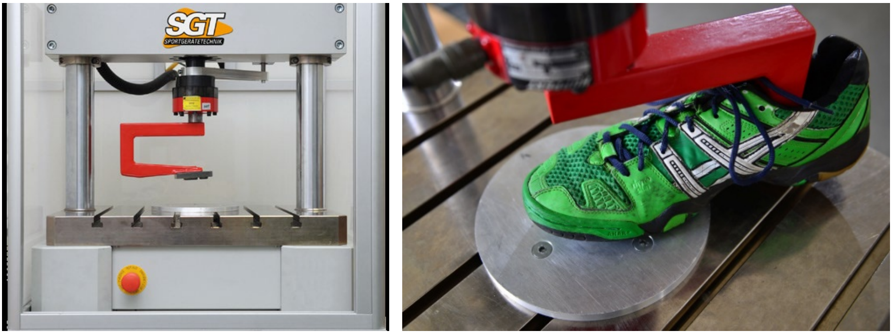

(a) (b)

Fig. 1: Mechanical simulation for testing forefoot cushioning, (a) forefoot indenter clamped into the testing machine, (b) clamped test shoe.

To verify the suitability of the newly developed mechanical simulation (Fig. 1), a reliability study (one test shoe, two measurement days, a total of four test series with 20 consecutive cycles each) was first conducted. Then, a benchmark study was performed on 69 sport shoes to determine the material properties describing the shock attenuating properties.

The results obtained in the reliability study were found to be reliable, e.g. the mean and standard deviation of hysteresis energy ratio was 38.6 ± 0.9 %. The benchmark study could be carried out without any problems. The range of material properties of the shoes studied was large (Table 1).

Table 1: Selected material properties determined in a benchmark test with 69 different athletic footwear using the newly developed mechanical simulation.

	Min	Q25	Q50	Q75	Max
deformation maximum (mm)	13.7	17.5	19.8	23.6	32.4
overall stiffness (N·mm^{-1})	93	166	187	215	265
hysteresis energy ratio (%)	14.4	29.6	31.3	33.9	44.8

Based on the results obtained in the studies, the newly developed mechanical simulation for testing the forefoot cushioning of running shoes can be considered a suitable method for determining the material properties.

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