Dr. Heidinger &
Dr. Jaspert GbR
ERGONOMY INSTITUTE MUNICH

Schaffer
PurForm Technik GmbH & Co. KG
Porschestr.1

49356 DIEPFOLZ

01 March 2000

Ergonomic experiments on a workstation mat of Schaffer GmbH & Co.KG

TEST REPORT

[Signature]
Dr. Florian Heidinger

[Signature]
Dr. Bodo Jaspert

Publications from this test report, require full or partial prior approval of the author

EIM
Rosenheimer Strasse 30
81669 Munich

Phone 089-66 20 02
Fax 089-62 48 95 21
Email mail@eim-online.de
Internet www.eim-online.de

EIM Labor
Schwabener Weg 12
85630 Neukeferloh

Phone 089-46 20 14 71
Fax 089-46 20 41 70

Institutsleitung:
Dr. oec. troph. Florian Heidinger
Dr. Ing., Dipl.-W. Ing. Bodo Jaspert

HypoVereinsbank
BLZ 700 202 70 Kto. 469 55749
Kreissparkasse Munich
BLZ 702 501 50 Kto. 940 1241

1. Preliminary observation

In addition to the prevalent requirements for workstation mats e.g. burning properties, thermal insulation effect, handling and cleaning options, their **load - reducing effect** on the human supporting and musculoskeletal system from the point of view of ergonomy are in focus, whereby conditions, in this respect, must be improved in comparison to floors that are usually hard, that is, floors that have no or hardly any elastic cushioning.

The following general requirements must be laid down with respect to the load - reducing properties of workstation mats:

- The **pressure distribution under the foot sole** should, to the maximum extent possible, not have any peak loads while walking that could lead to pressure pain in the feet.
- **The peak loads occurring with impact** while walking in the course of a rolling movement (so - called ‘passive peak forces that occur shortly after the touching of the heel to the ground) should be minimized, to the maximum extent possible, so as to minimize joint stresses.

It makes sense to develop a link between the physical and the human- physiological measurements to be able to evaluate the load situation with respect to the aforementioned criteria.

Physical tests (Determination of spring characteristic curve, see Chapter 3 and vertical force measurements at impact load, see Chapter 5) enable exact material - physical measurement recording. The methods used go beyond the purely technical character of the test, insofar as they are approximated to the real situation of the walking human, with respect to the execution of the test.

Human physiological tests with two test persons (measurement of the pressure distribution under the foot sole, see Chapter 4 and measurement of the impact load during the rolling movement, see Chapter 6) provide direct statements about the load situation with respect to walking persons.

The human- physiological measurements were carried out with two different **sole structures** (fairly soft, fairly hard), as the load acting on the body while walking does not depend merely upon the elastic-cushioning properties of the floor material, but also depends upon the features of the shoe sole.

2. Test materials

The tests described in the Chapters 3 to 6 were carried out on a **workstation mat of Schaffer GmbH & Co. KG** with the dimension 910mm x 655mm. The tested workstation mat is smooth on the bottom side and has a slightly coarse structure on the top side.

The main aim of this test is to determine the elastic-cushioning behaviour and thus, the load - reducing effect of this workstation mat. Additionally, measurements were carried out under the test condition **'hard base'** for comparison, whereby the same was simulated in the test by an almost non-elastic Parkett – wooden floor.

3. Physical measurements of the spring characteristic curve

3.1 Test process

The elastic-cushioning effect of the Schaffer-workstation mat was determined with the help of a specially developed measurement process oriented to real conditions while walking, as the hardness test as per Shore A and D (DIN 53505) does not provide adequate information due to following reasons:

- Only **one** test value results from the hardness test as per Shore A and D, however it does not result in a continuously drawn spring characteristic curve. However, a progressive, linear or degressive change of force at increasing load of the test material influences the force reduction at the load change;
- The test material is only **statically** loaded in the test as per Shore A and D. However, walking and postural changes are dynamic actions, whose material - physical evaluation also requires **dynamic test methods**;
- The prescribed **test stamp area** is significantly smaller than the load - bearing shoe sole surfaces, because of which surface tension effects can be produced in case of testing as per DIN 53 505, which falsify the test result.

Due to the aforementioned reasons, the workstation mat was tested with a special measurement setup, the test conditions of which were determined such that a real walking situation was simulated:

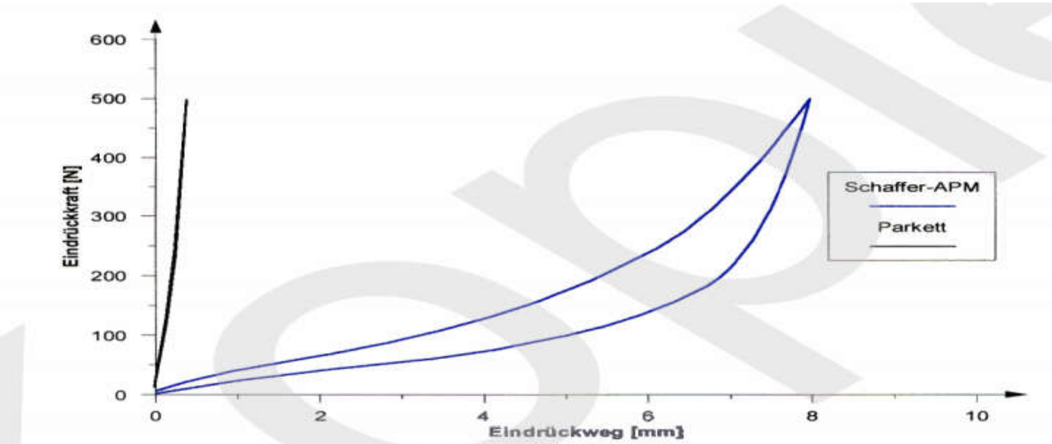
- Spring characteristic curves were drawn (Force-/path diagrams), whereby the test material was dynamically loaded/unloaded with a test speed of 1000mm/min. The selected load speed results from the following context:
Ground contact time of approx. 0.7 s. results at an average walking speed of approx. 5 km/hour. Under the assumption of a rear foot and forefoot load of same duration and with the assumed deformation path of the material sample of approx. 3mm (corresponding to 6mm for load and relief) the load speed of the ground is calculated at an average to v = approx. 6mm/0.35 s, thus approx. 100 mm/min;
- The test stamp surface amounts to 10cm^2, the sample preload 5 N.

3.2 Results and discussion

The tests of the spring characteristic curve described in the previous chapter were carried out on the **Schaffer – workstation mat** and also on the **hard base**.

Strictly speaking, a measurement of the test condition ‘hard base’ would not be possible, as there can be no deformation path here as per definition, so a parkette wooden base that does not have any elastic cushioning properties was used as test condition ‘hard base’.

Figure 1 shows the spring characteristic curves (respectively the load and relief curves) for the two tested materials.



Eindrückkraft = Stroke power
Eindrückweg = Stroke path

Fig. 1: Measured spring characteristic curves on the Schaffer-workstation mat (APM) as compared to hard base (Parkett -wooden floor)
Dynamic load: Test stamp surface $10cm^2$; Test speed 1000mm/min

The following can be derived from the curve courses shown in Figure 1

- the ‘**hard base**’ used as **reference** (Parkett- wooden base) does not have any elastic-cushioning function, thus it has only a minimal deformation path even at high load;
- the **Schaffer- workstation mat** has a clear elastic deformation, whereby a cushioning that is quite pronounced, can be measured.

The **characteristic curves** of the two base materials show basically different behaviours: The linear, steeply rising curve of the Parkett-wooden base indicates the hard spring - elastic behaviour with constant hardness properties; whereas the tested Schaffer- workstation mat initially shows a very soft elastic behavior with a progressively rising course of the curve in the higher load range.

While in the substantially hard wooden – Parkett base, the load and the unload curve practically proceed congruently – as an expression of the material behaviour without any cushioning–a significant **cushioning proportion** is reflected in the Schaffer- workstation mat (deviation between the load curve and the unload curve).

The objective of the tests in the Chapters 5 and 6 is to observe how this material - physical manifested cushioning proportion of the Schaffer- workstation mat has an effect, in case of the reduction of the high frequency force peaks (Impact load at the striking of the heel to the ground at the beginning of a rolling movement).

4. Human physiological pressure distribution measurements

4.1 Test process

Flexible measurement mats were used for recording the pressure distribution under the foot soles inserted between the foot and the inner sole of the shoe during the measurement. These measurement mats are equipped with capacitive pressure sensors. The pressure values under the foot sole resulting during the rolling movement are continuously recorded with the help of special control and imaging electronics.

The related tests were performed with a female test person (Test person 1: Age: 28 yrs., Height: 168 cm, Weight 58kg) and a male test person (Test person 2: Age: 35 Height: 182 cm, Weight 82kg).

The pressure distributions of the foot rolling movements at average walking speed (approx. 5km/h) and average step width (approx. 0.8m) were measured during the ground contact. Thus, multiple individual pressure distribution diagrams emerge for every rolling movement (approx. 30 measurement diagrams) corresponding to the sampling frequency of the measurement process (40Hz).

Individual phases of the rolling movement are shown with the help of color coded representations in Figure 2 for illustration. These color displays show

- the initial contact in the heel area when the heel strikes the ground
- further rolling over the lateral foot edge
- full foot contact
- lifting of the heel
- the pushing away of the foot over the forefoot pad and the toe area.

A so- called maximum pressure pattern is synthesised from the individual pressure distribution images of a rolling movement for a clear result illustration and evaluation. This maximum pressure pattern is a sum of the individual phases of the rolling movement: Maximum pressure value occurred at every measuring point is shown, which was measured during the rolling movement. A maximum pressure pattern synthesised in this manner is shown as an example in Figure 3.

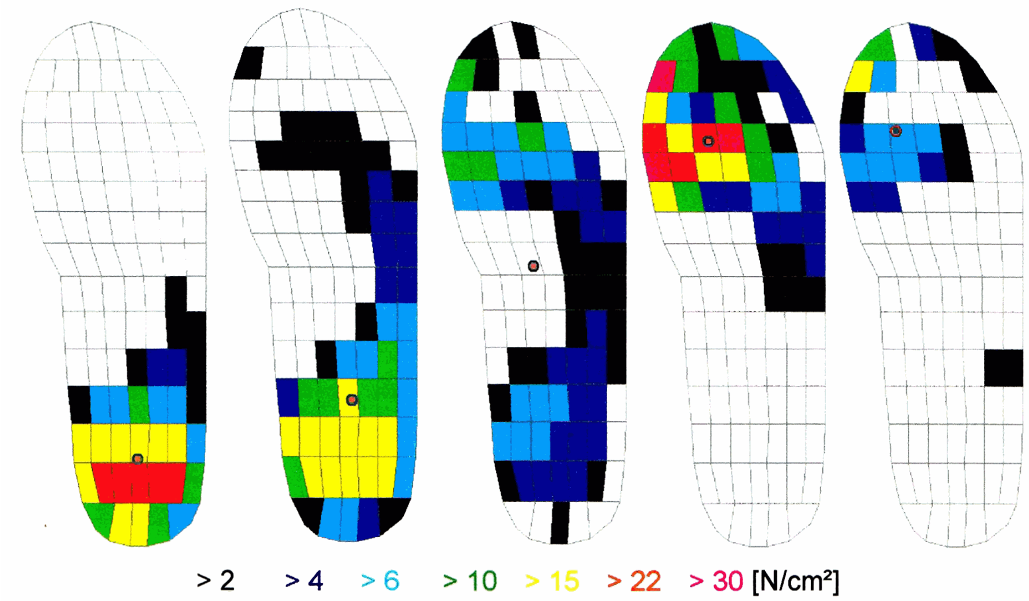


Fig. 2: Selected phases of the rolling movement. For description of the phases, see the text

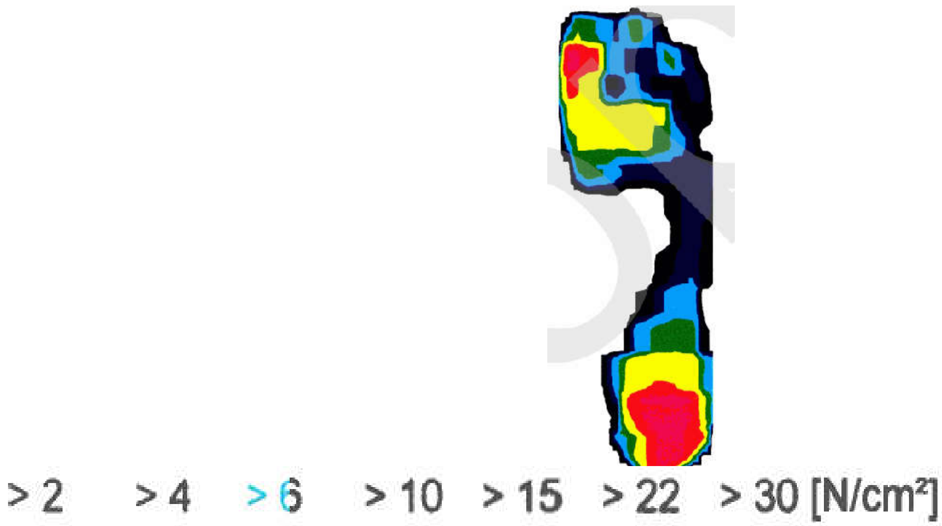


Fig. 3 Synthetic maximum pressure pattern in color - coded isobar diagram for a rolling movement.

3.3 Results and discussion

The pressure values were recorded under the foot sole of both the test persons while walking on both the base variants, thus on the Schaffer -workstation mat and on the hard base. Moreover, the pressure distribution measurements of the rolling movements were performed with two different shoe variants so that the effect of the shoe material could be quantified.

- Shoe type1, with fairly thin, soft sole structure (elastic);
- Shoe type, with fairly thick, hard sole structure (mainly non-elastic).

The pressure distribution measurements carried out as examples in a standing position, did not show any assessable differences between both the base options. This finding can be explained by the fact that primarily, the footwear worn determines the static pressure values between the foot and the shoe. A dynamic, elastic -cushioning impact of the ground does not necessarily come into effect in this test situation.

The results of the dynamic pressure distribution measurements (walking) are available in the Figures 4 to 7 in form of maximum pressure patterns.

For the purposes of a clear result illustration and discussion, the respective maximum pressure values occurred in the rear foot area were derived from these maximum pressure patterns. These characteristic values are depicted as a summary in Table 1.

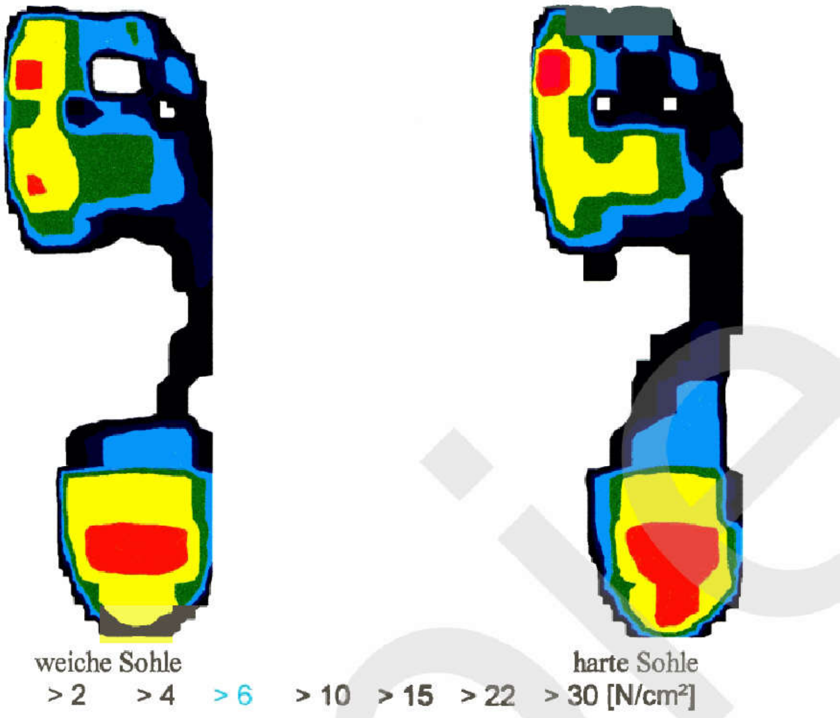
Tab.1: Measured maximum pressure values (N/cm^2) in the course of all the rolling movements in the rear foot area on the Schaffer-workstation mat and on a Parkett-wooden floor for both the test persons, respectively with fairly soft-elastic and fairly hard shoe sole structures (see Fig. 4 to 7)

Lining option	**Maximum pressure values [N/cm^2]**			
	Vp 1		**Vp 2**	
	Soft sole	**Hard sole**	**Soft sole**	**Hard sole**
Schaffer- APM	26	29	18	24
Parkett	31	39	22	29

The following conclusions can be drawn from the maximum pressure values shown in Table 1

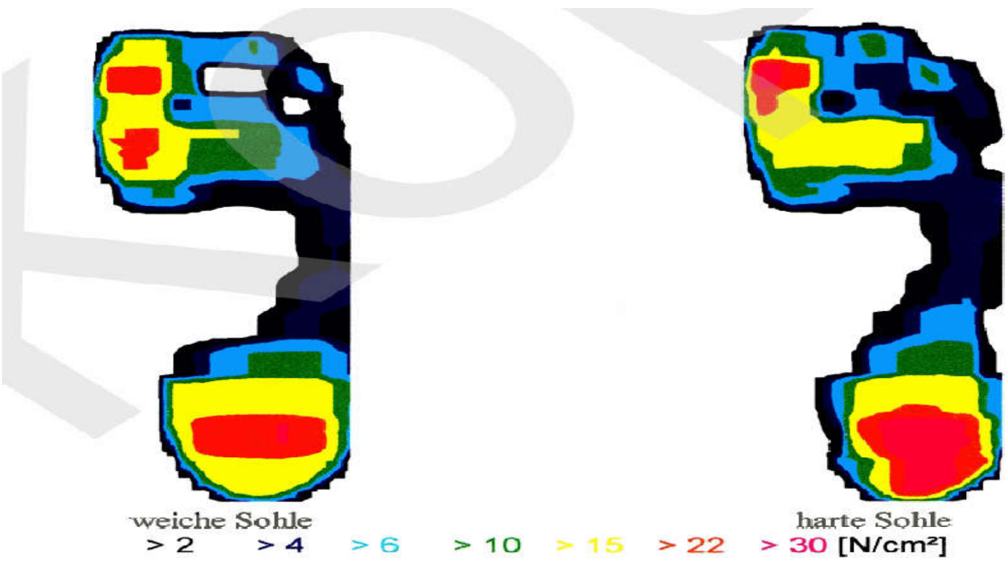
- The **individual rolling behaviour** of both the test persons differs basically to the extent that in case of Test person 1, higher pressure values occur in spite of lesser body weight than in case of Test person 2;
- The measured **peak pressure values** are significantly lower in case of the use of the softer shoe sole structure than (on an average at around 20%) than in case of the harder sole structure.
- The peak pressure values are generally significantly lower (on an average around 20%) in case of the Schaffer – workstation mat as against the harder sole structure;
- The **soft-elastic functioning** of the Schaffer-workstation mat is pressure reducing; and thus load reducing when fairly hard and largely non-cushioning footwear is worn.

The temporary resolution of the individual measurements is limited for the pressure distribution measurement used here because of multiple individual measurement points.
Accordingly, the force peaks occurring very frequently at the beginning of the rolling movement (so called ‘passive force peaks’; see Chapter 5 and Chapter 6) cannot be recorded by this measurement method because of which special tests are additionally carried out for this purpose.



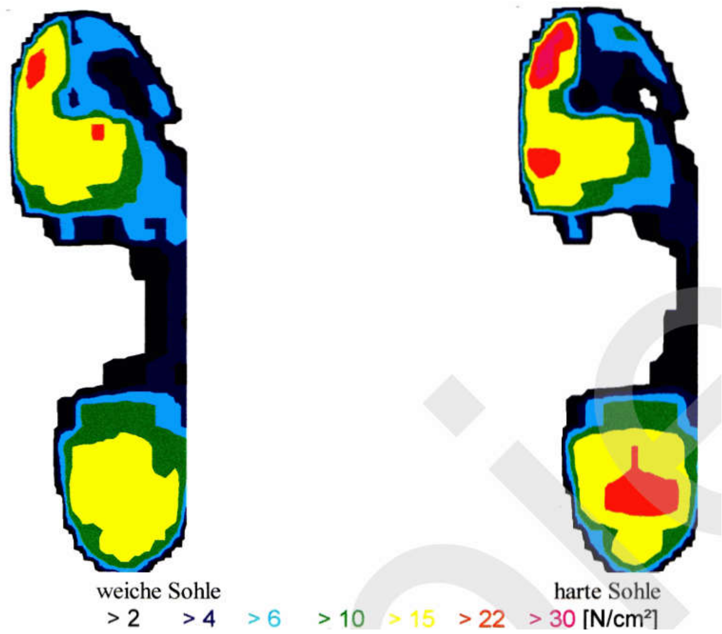
Weiche Sohle = Soft sole harte Sohle = hard sole

Fig. 4: Maximum pressure patterns for the rolling movements: **Schaffer – workstation mat, Test person1**fairly**soft** (left) and fairly **hard** (right) sole structure



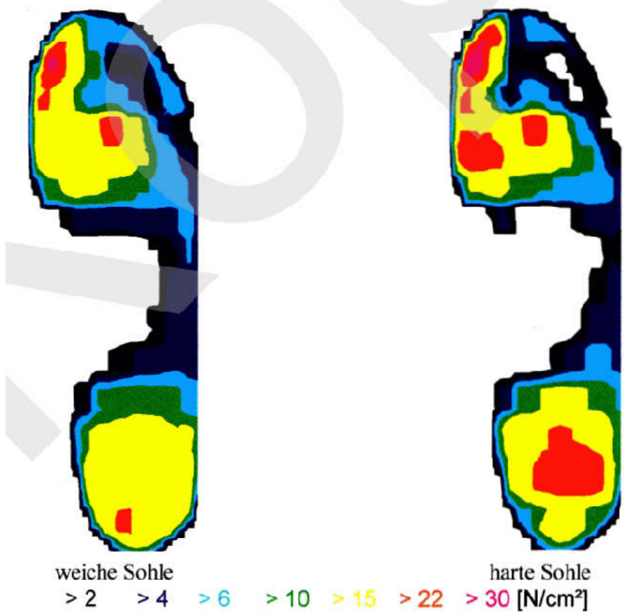
Weiche Sohle = Soft sole harte Sohle = hard sole

Fig. 5: Maximum pressure patterns for the rolling movements: **Parkett – wooden base (hard base), Test person 1**fairly**soft** (left) and fairly **hard** (right) sole structure



Weiche Sohle = Soft sole harte Sohle = hard sole

Fig. 6: Maximum pressure patterns for the rolling movements: **Schaffer – workstation mat, Test person 2**fairly**soft** (left) and fairly **hard** (right) sole structure



Weiche Sohle = Soft sole harte Sohle = hard sole

Fig. 7: Maximum pressure patterns for the rolling movements: **Parkett – wooden base (Hard base), Test person 2**fairly**soft** (left) and fairly **hard** (right) sole structure

5. Physical measurements for impact load

5.1 Test method

As discussed in Chapter 3.2, the adjustment of the elastic-cushioning characteristics of a floor lining material is significantly important for the load reduction: High loads on the joint chains and the strong cushioning characteristics are the results of very hard spring elastic adjustment. Impact load is simulated in this test layout for reducing the aforementioned so-called passive force peaks, as it especially concerns the 'quickness' of the elastic – cushioning material behaviour while walking.

The impact is initiated in the measurement method applied, with the help of metal ball (m= 5kg), which is dropped from a height of 25mm on the respective test floor. The vertical force resulting thereby is recorded by a measuring platform, which is positioned below the floor lining to be tested. DMS- force measuring probes are fitted in this measuring platform, whose load proportional voltage signal is recorded by a measuring computer with a sampling frequency of 3000 Hz and it is subsequently evaluated.

5.2 Results and discussions

In the tests for force peak measurement for impact load, both the base options were included (Schaffer- workstation mat, hard Parkett-wooden floor).

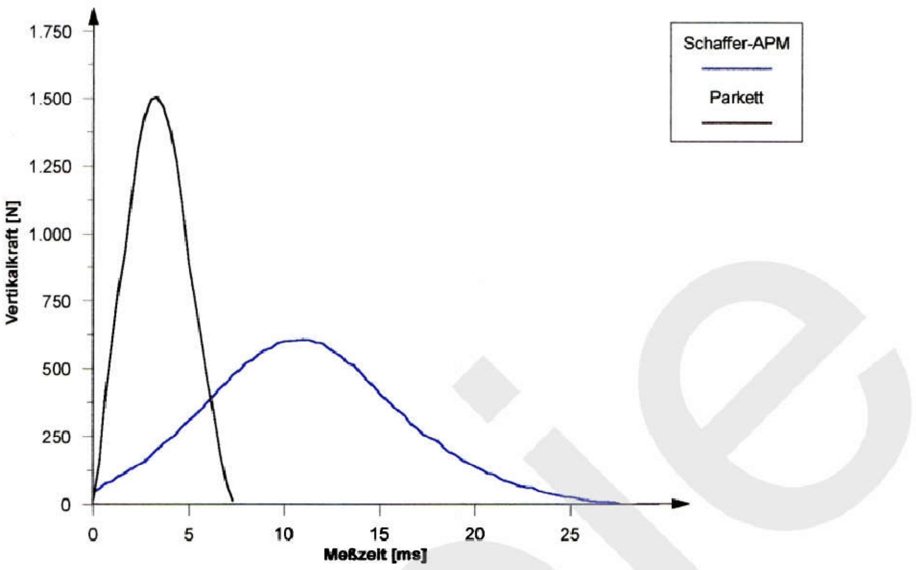
In Fig. 8 the **force curves** of the related measurements in the first 30ms after the impact of the metal ball are represented. The **force peak values** of these initial loading procedures are also shown in Table 2.

Table 2: Measured force peak values (in N) of the first loading cycle for impact load on the Schaffer -workstation mat compared to the hard Parkett - wooden floor (see Figure 8).

Lining options	Force peak values
Schaffer-APM	609
Parkett	1507

The results from Figure 8 and Table 2 show:

- A reduction of force peak value by approx. 60% results when the workstation mat is used, as against the use of hard base.
  In conjunction with the comparably flat increase of the vertical force, a distinct load - reducing effect of the Schaffer -workstation mat can be expected from this material - physical test as against hard base in the real walking test (see Chapter 6).



Vertikalkraft = Vertical force Meβzeit = Measuring time

Fig. 8: Measured vertical force curves (in N) of the first loading cycle for impact load on the Schaffer – workstation mat (APM) compared with hard base (Parkett- wooden floor).

Eventually the effect of the base material in this test depends upon its proportionate elastic and cushioning characteristics under impact load.
In principle, a higher ratio of cushioning, with respect to the material behaviour, is problematic insofar as a high ratio of cushioning can have the hardening effect for impact load because the cushioning effect depends directly on the load speed: A material deformed with high loading speed acts harder, the more pronounced its cushioning behavior is.
From an ergonomic perspective, this connection is significant insofar as it concerns the 'quickness' of the elastic – cushioning material behaviour while walking, running and jumping because, only the quality of the base is responsible for the loading of the joint chain ('Passive force peaks') after the heel strikes the ground. The active, muscular cushioning system of a human being cannot influence these rapidly occurring 'passive force peaks' because of very long durations in the transmission of nerve stimuli for the same.

As per these statements, the material behaviour of the base is particularly responsible for the load due to 'passive force peaks' – the temporarily following 'active force peaks' are mainly cushioned by muscles and they are not influenced by the base (see Chapter 6.2).

6 Human physiological measurements for impact load (passive force peaks)

6.1 Test process

To be able to make a statement for impact load during the rolling movement (passive force peaks) under real walking conditions, the relevant human - physiological measurements are carried out with both test persons in addition to the physical tests described in Chapter 5.

For this purpose, the test materials are placed on the already described measuring platform. The test persons (for test person details, see Chapter 4.1) walked over the respective test material with defined speed (approx. 5km/h; approx. 0.8mm step width), whereby the influence of the footwear was also taken into consideration.

The vertical forces occurring during the rolling movement were recorded.

6.2 Results and discussion

The relevant test results of the human - physiological vertical force measurements are shown in Figures 9 to 12.
For a clear representation of the result, the force values of the active force peaks, which occur around 20 to 40ms after the heel strikes the ground, are summarised in Table 3.

Table 3: Force values (N) of the so - called passive force peaks, approx. 20 to 40 ms after the heel strikes the ground, for both test persons on the Schaffer- workstation mat and on a Parkett-wooden floor during the rolling movements, respectively with fairly soft and fairly hard sole structure (seeFig.9 to Fig. 12)

Lining options	**Test person1**		**Test person 2**	
	Soft sole	**Hard sole**	**Soft sole**	**Hard sole**
Schaffer-APM	-----*	543	----*	636
Parkett	434	667	----*	859

*: No passive force peaks resolvable

The result illustrations of Figures 9 to 12 and Table 3 permit the following statements:

- Systematic differences are seen between both the base variants, practically only to the extent of the so - called passive force peaks, thus around 20 to 40 ms after the heel strikes the ground. The force peak values occurring in this phase of the rolling movement are eventually dependent upon the elastic-cushioning properties of the base (floor lining, shoe sole structure).

The **active force peaks** following in the further course of the rolling movement (rolling of the rear foot: approx. 100 to 300ms; rolling the forefoot: approx. 300 to 700ms) appear to be largely uninfluenced by the base as the muscle system actively acts as a cushioning factor here.

Therefore, the passive force peaks are of significance because they have an effect on the complete human joint chain, practically without cushioning, while the active force peaks can be reduced by the muscle system.

- As emerges from the values shown in Table 3, these passive force peak values can occur distinctly when hard shoe sole structure is used.
  When an already **soft-elastic shoe sole** is used, then the passive force peaks can lie in a resolvable size, when the base is practically non-elastic:
  Thus, a significant 'passive force peak' results for Test person 1 in spite of the soft-elastic sole structure under the test condition 'hard base', while it is not resolvable with respect to the use of the Schaffer-workstation mat.
- In case of fairly **hard, non-elastic shoe structure,** 'passive force peaks' also occur when the Schaffer – workstation mat is used, however, these lie at around 20% to 25% lower than the passive force peak values in the test condition 'hard base'.
- In principle, the same is applicable as in the human - physiological pressure measurements (see Chapter 4.2) that the differences between both these base variants are more distinct, when hard footwear is used that has hardly any elastic effect. In this case, the Schaffer-workstation mat offers a considerable force peak-reducing and thus, load-reducing effect as compared to the hard, mainly non-elastic base.
  The base-related differences of the elastic behaviour are weakened when a soft-elastic shoe sole structure is used.

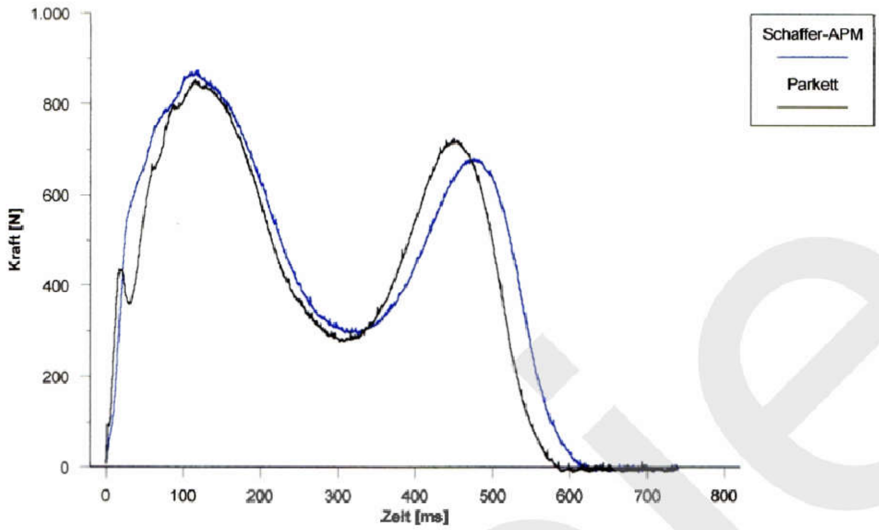


Fig. 9: Vertical force curves during the rolling movements on the Schaffer – workstation mat (APM) compared to hard base (Parkett- wooden floor).

Test person 1, fairly soft shoe structure

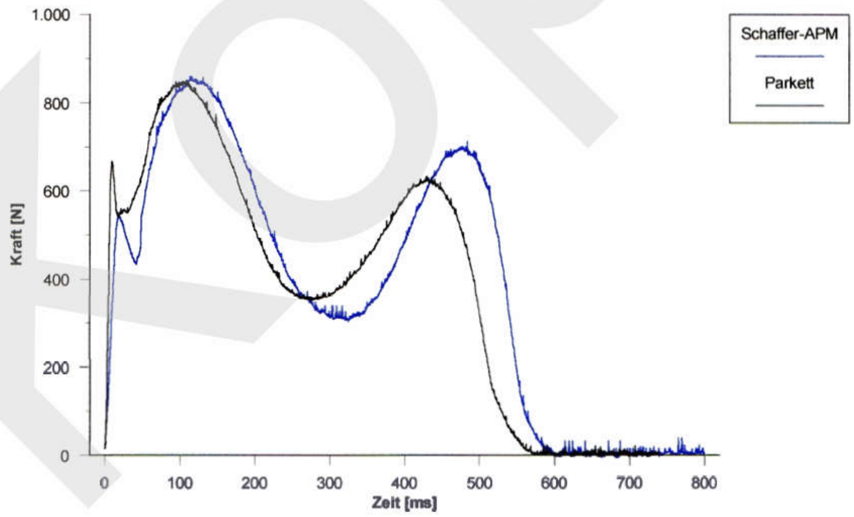


Fig. 10: Vertical force curves during the rolling movements on the Schaffer – workstation mat (APM) compared to hard base (Parkett- wooden floor).

Test person 1, fairly hard shoe structure

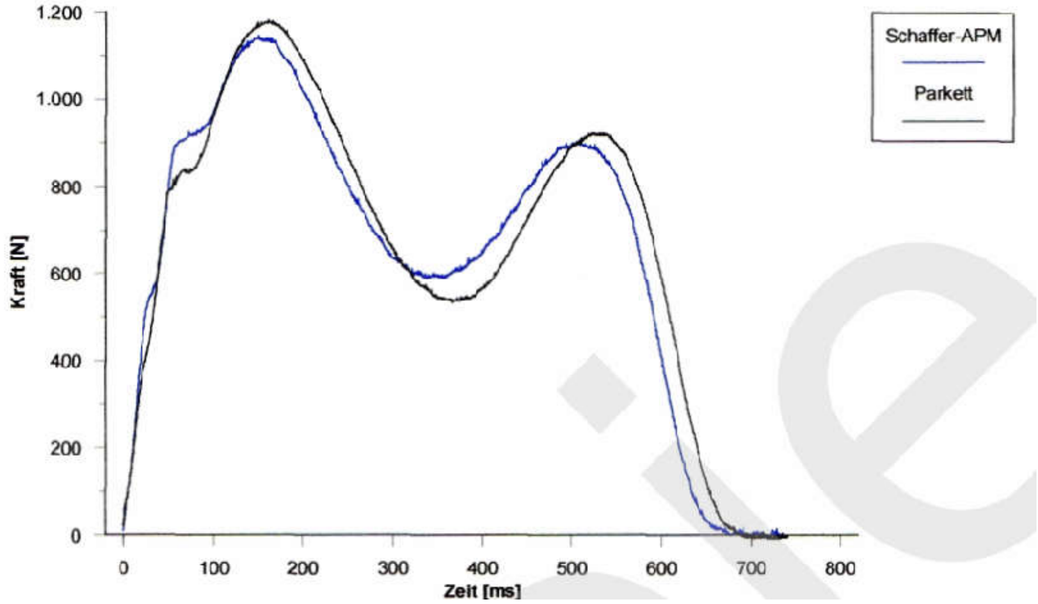


Fig. 11: Vertical force curves during the rolling movements on the Schaffer – workstation mat (APM) as compared to hard base (Parkett- wooden floor).

Test person 2, fairly soft shoe structure

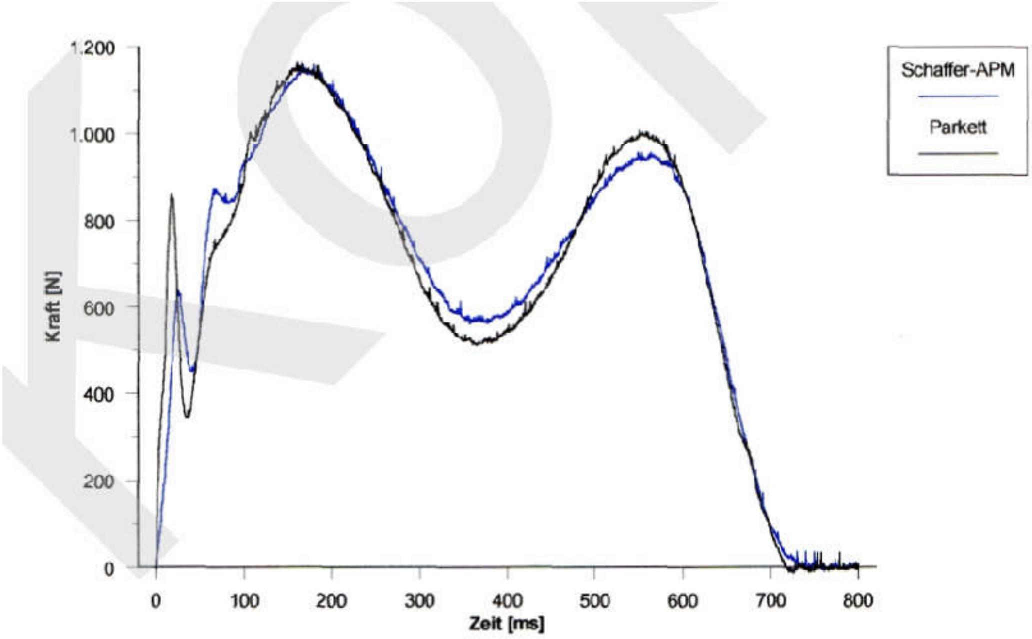


Fig. 12: Vertical force curves during the rolling movements on the Schaffer – workstation mat (APM) compared to hard base (Parkett- wooden floor).

Test person 2, fairly hard shoe structure

7. Summary

From an ergonomic perspective, the behaviour of the floor linings plays a crucial role considering the aspect of **loading** of the supporting and musculoskeletal system. By using elastic cushioning materials, the conditions against the bases that are frequently hard, or that provide no or hardly any elastic-cushioning, should be improved.

It is well-known that the joints (foot, knee, hip and spinal joints) are the weak points of the human supporting and musculoskeletal system. Degenerative changes occur frequently in these areas because of long-standing exposure to inappropriate loads and overloads. To reduce the forces acting on the human body while standing, walking, running or jumping, the rolling movement of the foot should take place such that it is elastically cushioned. There are two options for the same:

- Use of **floor linings** with an elastically cushioning effect
- Use of **work footwear** with elastic - cushioned sole materials.

As regular working shoes are often used with very hard, non - flexible soles and thus, they do not have much elastic - cushioning effect, this function must be taken over by the floor lining. In this respect, the **workstation mats** made of elastic- cushioning material represent a sensible option for load reduction from an ergonomic point of view, insofar as the floor materials used in the industrial plants (concrete, screed etc.) are usually hard and non-cushioning.

In the tests presented here, a **workstation mat** of **Schaffer GmbH & Co. KG** is tested for its elastic-cushioning behaviour. The test condition '**hard base'** is used as **reference**, thus an almost non-elastic floor material (Wood-Parkett) is used.

The evaluation of the elastic - cushioning effect of the Schaffer-work station mat compared to hard base was conducted with the help of a combination of **physical** and **human physiological measurements**.

Furthermore, the elastic-cushioning behaviour of two different **shoe sole structures** (fairly soft-fairly hard) was included in the tests.

The **physical measurements carried out for spring cushioning behaviour** (see Chapter 3) showed that the Schaffer – workstation mat reacts quite elastic – with average spring-elastic hardness degree- depending on the material.

The **pressure distribution measurements under the foot sole** (see Chapter 4) delivered a significant peak pressure reducing effect (on an average, approx. 20%) for both test persons in dynamic load case (walking) on the tested workstation mat compared to the hard base. The load reducing effect is particularly evident when hard shoes are worn with a mainly non-elastic sole structure.

Apart from this, **the behaviour** of workstation mats **in impact loads** is applied as an important criterion with respect to a load reducing effect. The relevant physical (see Chapter 5) and human-physiological tests (see Chapter 6) were carried out on the Schaffer -workstation mat from that point of view:

There is a significant reduction of the measured force peak values by approx. 60% compared to the hard base in the **physical test for impact load** because of soft elastic effect with a simultaneous rather low cushioning percentage of the Schaffner workstation mat.

This positive effect of the workstation mat was evident in both test persons in the **human physiological test** in a significant reduction of the so-called passive force peak values compared to walking on hard base. This load reducing effect was mainly evident when hard shoes were worn- here 20% to 25% lower passive force peak values as compared to hard base could be measured in the rolling movement on the Schaffer- workstation mat.

The passive force peak values are particularly significant from the biomechanical perspective mainly because they occur within a very short time (few milliseconds) after the heel strikes the ground and therefore cannot be reduced by the active, muscular cushioning system of the human body.

The tests carried out prove that the **quality of the base material** in view of its elastic cushioning behaviour, has a major effect on the **pressure load during the rolling movement and the impact load when the heel strikes the ground**.

Particularly when mainly hard shoe sole material is worn, then a significant, measurable **load reducing effect** can be obtained using the **Schaffer-workstation mat** as against hard, non-elastic base conditions.