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THE EFFECT OF FORWARD LEANING ON LUMBAR INTRADISCAL PRESSURE

By

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Many calculations have been made of the load on the lower intervertebral discs in the forward bending position, (*Bradford & Spurling* 1947, *Waris* 1949, *Mathias* 1956, *Perey* 1957). In this position carrying of weights has been said to increase the load on the disc by five (*Waris* 1948) to ten (*Bradford & Spurling* 1947, *Perey* 1957) to twenty (*Mathias* 1956) times the weight carried.

No measurements of the intradiscal pressure in the forward leaning position have been reported. This study presents data of the intradiscal pressure and to what extent it increases by forward leaning with or without weight bearing.

METHODS

The method used for intradiscal pressure measurements *in vivo* has previously been described (*Nachemson & Morris* 1963, 1964) (Fig. 1).

In the present study the eight patients were first measured in an upright sitting position. Two of them were also examined standing. The interspace to be measured was localized by a roentgen image intensifier apparatus. After three consecutive measurements in the upright position the patient was told to lean forward twenty degrees *i.e.* to flex in his hips and hold his back straight. The forward angulation was measured. (Fig. 2). Measurements were made and again repeated with the patient holding five and ten kilogram weights, respectively, in his hands in the same forward leaning position.

It is important to hold the pressure transducer horizontal during the measurements. The guide needle and also the transducer with the measuring needle therefore have to be inserted horizontally when the patient is sitting in an upright position. The needle with the pressure sensitive membrane, however, will allow bending of twenty degrees without impairing the results (*Nachemson* 1960). Technical circumstances thus make measurements with forward leaning positions exceeding twenty degrees practically impossible with the present method.

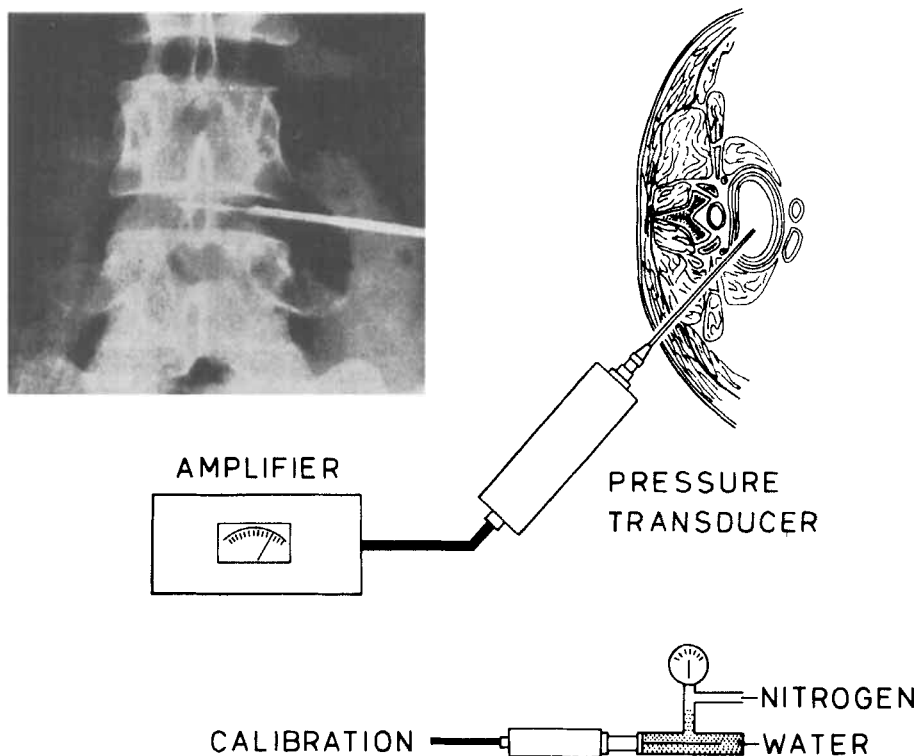


Fig. 1.

Schematic drawing of the method used for intradiscal pressure measurements *in vivo*.

MATERIAL

Pressure measurements were made in a roentgenographically normal third or fourth lumbar disc in eight patients admitted to the hospital for low back pain or sciatica (Table 1). In all cases the nucleography, performed after completion of the measurements was normal. In some instances the series of measurements was interrupted because of the patient's discomfort (Table 2).

RESULTS

In Table 2 are shown the pressures obtained when measurements were made in the forward leaning position of ten and twenty degrees with and without additional loads of five and ten kilograms in each hand. The pressures obtained in the sitting position were of the same magnitude as those previously reported (*Nachemson & Morris 1964*).

When the patients leaned forward 20 degrees, values ranging from

TABLE 1
Summary of Data on Subjects.

Case no.	Age yr.	Sex	Weight kg	Height cm	Body structure	Disc Level	Disc Condition	History
1	45	M	75.0	175	moder.obese	L-3	normal	Low back pain 6 mo. Back to work 4 w. after discharge.
2	43	M	77.0	173	muscular	L-3	normal	Op. hernia L-5, 1962. Low back pain > 1 year.
3	22	F	67.0	163	moder.obese	L-3	normal	Back to work 6 w. after discharge. Low back pain 6 mo.
4	44	M	76.8	173	well-developed	L-3	normal	Back to work 3 mo. after discharge. Sciatica 3 mo. Op. hernia L-4 2 w. after discometry.
5	41	M	76.2	186	well-developed	L-3	normal	Low back pain 2 mo.
6	49	M	94.0	183	obese	L-4	normal	Back to work 3 w. after discharge. Sciatica 2 mo. Myelogram neg.
7	35	M	65.7	179	slender	L-3	normal	Back to work 2 mo. after discharge. Low back pain 4 mo.
8	43	M	74.0	176	well-developed	L-4	normal	Back to work 2 w. after discharge. Low back pain 2 mo. Back to work 3 w. after discharge.

TABLE 2
Results Obtained with Subjects in the Sitting Position.

Case no.	Disc level	Disc area cm ²	Body weight above disc kg (W)	Pressure measured P _n kg/cm ²	Total load on disc P kg	Forward leaning 10-20 degrees P _n kg/cm ²	P kg	Forward leaning 10-20 degrees 5 kg each hand P _n kg/cm ²	P kg	Forward leaning 10-20 degrees 10 kg each hand P _n kg/cm ²	P kg
1	L-3	18.0	42.8	12.3	147.6	17.6	210.6	20.3	243.0	18.7	252.5
2	L-3	20.2	43.9	11.3	151.5	14.1	189.9	16.9	228.3		
3	L-3	14.4	38.2	11.5	110.9	15.8*	151.2*				
4	L-3	16.2	43.8	12.7	137.7	15.8*	170.6*	23.1	249.5	27.3	294.8
5	L-3	21.8	43.4	10.6	153.5	12.3*	179.0*	15.4*	224.5*	23.5	336.0
6	L-4	55.5	55.5	11.4	162.6	16.2	231.1	18.7	267.5		
7	L-3	20.6	37.4	10.2	140.1	13.4	183.3				
8	L-4	19.8	43.7	10.6	140.6	12.7*	168.3*	13.7*	182.2*	16.2*	213.8*

* = Forward leaning of 10 degrees.

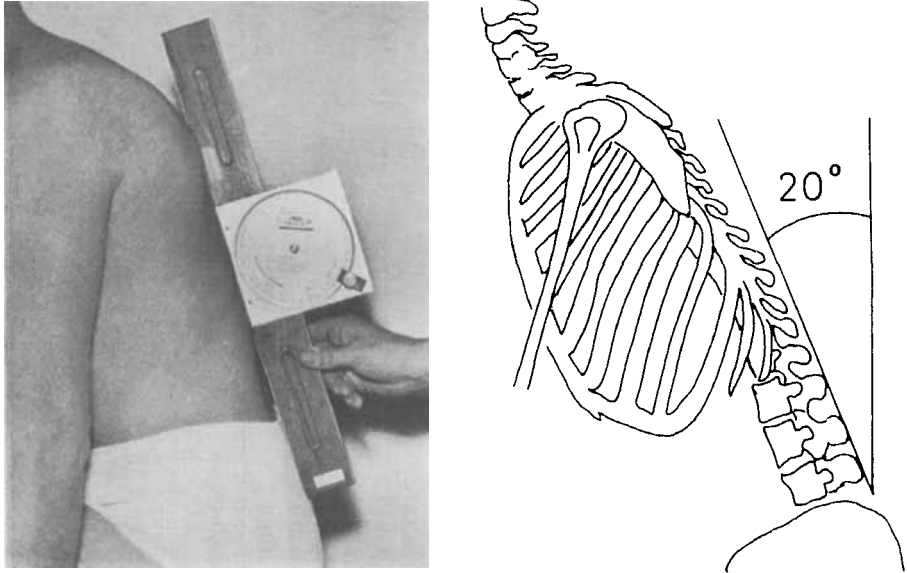


Fig. 2.

Method of estimating the angle of forward leaning. The protractor has a water level that can be preset at desired angle. In the fig. this angle is 20°.

13 to 18 kg/cm² were recorded. All individuals showed higher pressures compared to the upright sitting position. This increase averaged 30 per cent. When holding weights of 5 and 10 kilograms in each hand the values rose (19–27 kg/cm²).

The tables also indicate the load on the whole discs. These values are obtained by dividing the pressure by 1.5 and then multiplying this by the cross section area of the disc. (*Nachemson 1960, Nachemson & Morris 1964*).

The total load on the third and fourth lumbar discs in the forward leaning position of 20 degrees was between 180 and 230 kilograms. With 10 kilograms in each hand loads of 250–340 kilograms were noted.

DISCUSSION

Sitting Position.

In an earlier presentation it was demonstrated that the load (P) on the L. III or L. IV level in the upright sitting position is related to the body weight (W) above the level measured. This weight (W) was calculated according to *Ruff's* (1945) data which stated that approxi-

TABLE 3
Results Obtained with Subjects in the Standing Position.

Case no.	Disc. level	Disc. area cm	Body weight above disc. kg (W)	Pressure P_n kg/cm ²	Total load P kg	Forward leaning 10-20 degrees P_n kg/cm ² P kg	Forward leaning 10-20 degrees 5 kg each hand P_n kg/cm ² P kg	Forward leaning 10-20 degrees 10 kg each hand P_n kg/cm ² P kg
6	L-4	20.6	55.5	9.4	136.1	17.5	250.4	280.3
8	L-4	19.8	43.7	6.0	79.2	128.7*	152.5*	182.2*

* = Forward leaning of 10 degrees.

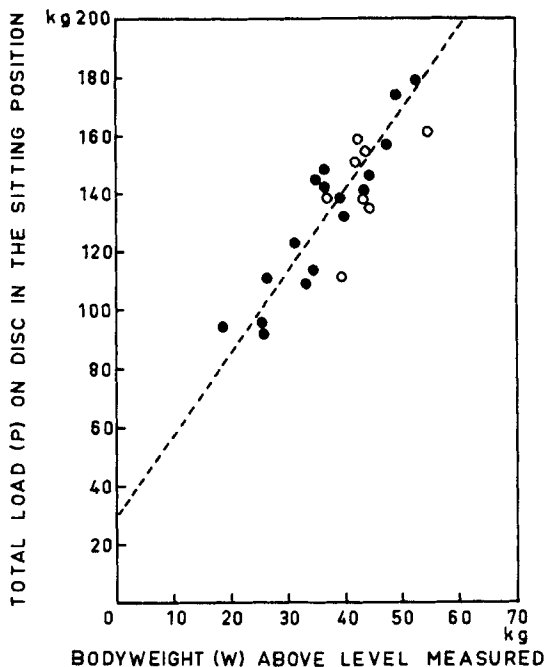


Fig. 3.

Relation between total load (P) on normal lumbar disc and calculated part of body weight above that level (W), sitting position. The slope was determined by means of regression. The values obtained in the present series are represented by circles, results previously reported by black dots.

mately 60 per cent of the body weight was above the center of L. V vertebra, with a decrease of 2 per cent for each lumbar vertebra upwards (*i.e.* above L. IV disc 59 per cent, L. III disc 57 per cent).

The relation between body weight and load on the disc (L. II, III and IV) can be written:

$$(1) \quad P_{\text{sitting}} = P_0 + kW$$

When the patient is sitting the factor k was found to be approximately 2.8 (Fig. 3). P_0 denotes the intrinsic pressure of the disc which is approximately 30 kg in this position.

The observations made on the load in the upright sitting position in the present series have supported the earlier demonstrated equation (1) (Table 2, Fig. 3).

Any value of the load on the lower lumbar interspaces in the for-

ward leaning position, based on theoretical calculations only, is apt to have several inherent errors. In the present study it has been demonstrated that the initial load, for example, is much higher than was previously thought.

In the calculations made by previous authors (*Bradford & Spurling 1947, Morris et al. 1961*) on the load on the lumbar discs in the forward bending position, the lengthening of certain lever-arms were considered. These distances can only be approximately estimated, due to the lack of determinations of the location of the line of gravity for the upper part of the body in the forward leaning position.

On forward bending with or without weight bearing it is, however, obvious from the results that a certain amount of load must be added to the disc because of the lengthening of some lever-arms. The center of gravity moves forward and the arms are held at a variable distance from the disc. These lever-arms should be approximately proportional to the sin of angle of forward bending (α), and thus the added load also should be approximately proportional to $\sin \alpha$. (Fig. 2).

In the sitting and forward leaning position, the total load (P) on the third or fourth disc can be approximately expressed by the following equation.

$$(2) \quad P_{\text{sitting}} = P_0 + kW + k_1 W \sin \alpha$$

TABLE 4

Values for k_1 Derived from Table 2 According to the Equation:

$$P_{\text{sitting}} = P_0 + k W + k_1 W \sin \alpha$$

Case no.	k_1	Case no.	k_1
1	4.4 , 3.9	5	3.6 , 4.8
2	2.5 , 2.6 , 2.0	6	3.6 , 3.6 , 4.8
3	3.2	7	3.5
4	4.1 , 4.6 , 4.8	8	3.8 , 1.9 , 2.2

Mean: 3.6

Solving for k_1 , using the results shown in Table 2 will give $k_1 \approx 3.6$ (range 1.9–4.8). Each specific k_1 -value is shown in Table 4. When solving the eq. (2), P_0 was given the value 30 kg, k the value found in the upright sitting position in each case (2.1–2.9), W the body weight above the level measured and P_{sitting} the result obtained.

The increase of load on the discs resulting from forward leaning of 10–20 degrees in the sitting position, varies somewhat in different

TABLE 5
Comparison of Pressure Values for Sitting and Standing Positions, Old and New Series.

Case no.	Disc level	Disc area cm ²	Sitting position		Standing position		Body weight above kg	Decrease in P from values in sitting %	Sex	Age yr.	Weight kg	Height cm
			Pressure kg/cm ² P _n	Total load kg P	Pressure kg/cm ² P _n	Total load kg P						
<i>Old series</i>												
8	L-4	17.6	11.8	139.0	8.8	103.8	39.2	25	M	49	66.5	163
15	L-3	19.9	11.8	157.2	7.4	97.5	47.5	38	M	52	83.3	179
16	L-4	21.3	9.9	145.8	8.6	121.4	44.5	17	M	52	75.2	175
17	L-3	13.8	15.3	140.8	9.6	88.3	43.3	37	F	35	76.0	160
18	L-3	15.7	13.7	142.9	8.2	86.4	36.5	39	M	34	64.1	173
19	L-3	20.6	13.0	179.2	10.9	150.4	53.2	16	M	37	93.3	186
<i>Present series</i>												
1	L-3	18.0	12.3	147.6	10.2	122.4	42.8	17	M	45	75.0	175
2	L-3	20.2	11.3	151.5	7.0	94.6	43.9	37	M	43	77.0	173
6	L-4	21.4	11.4	162.6	9.4	136.1	55.5	16	M	49	94.0	183
8	L-4	19.8	10.6	140.6	6.7	98.1	43.7	37	M	43	74.0	176

individuals. One reason for this could be the individual variations in the lengthening of the lever-arms anterior to the spine.

By using results from measurements in eight individuals, the following mean values of the constants in eq. (2) are obtained:

$$P_0 = 30 \text{ kg}$$

$$k = 2.8$$

$$k_1 = 3.6$$

With these constants the eq. (2) holds approximately for forward leaning of ten and twenty degrees in the sitting position.

In the upright sitting position several authors have registered muscular activity in the sacrospinalis group of muscles (*Åkerblom* 1949, *Schobert* 1962). The forces exerted by these muscles have been said to balance the body against gravitational forces. The results obtained of the intradiscal pressure and of the load on the lumbar discs are higher than would be expected if these forces alone were responsible for the load on the disc. With all probability other forces too act on the lumbar spine. Whether these should be discussed in terms of ligamentous forces or muscular forces other than those exerted by the erector trunci, or some unknown mechanism, still has to be revealed.

The results reported in the present study demonstrate the increase resulting from added load in the forward leaning position. Earlier calculations (*Bradford & Spurling* 1947, *Waris* 1949, *Mathias* 1956, *Perey* 1957) on the effect of weight carrying, give values that are higher than those measured.

The load relieving effect of an increased abdominal pressure demonstrated by *Bartelink* 1957, *Davis* 1959, *Morris et al.* 1962 and *Eie & Wehn* 1962, is one mechanism that reduces the total amount of load on the lumbar discs.

Standing Position.

The data obtained in the standing position are presented in Table 5. In this Table are included results from an earlier investigation. The relation between body weight above the level measured (W) and the total load P on the disc in the standing position has not previously been mathematically expressed. In conformity with eq. (1) this can be written:

$$(3) \quad P_{\text{standing}} = P_0 + k_2 W$$

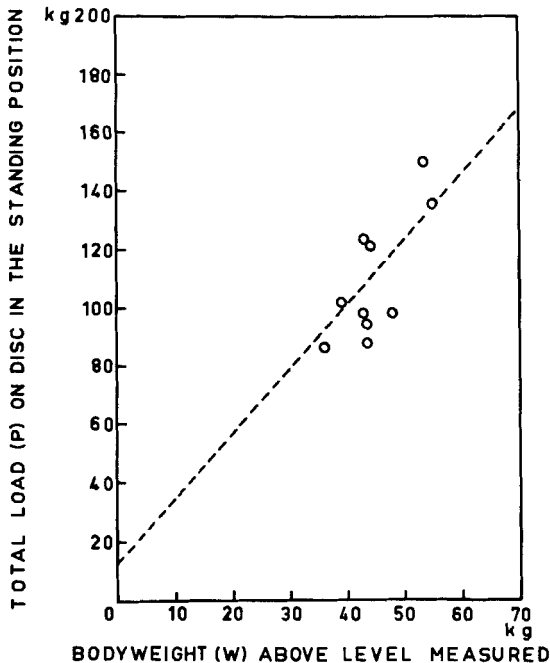


Fig. 4.

Relation between total load (P) on normal lumbar disc and calculated part of body weight above that level (W) in the standing position. (Table 5).

TABLE 6

Values for k_2 Derived from Table 5 According to the Equation:

$$P_{\text{standing}} = P_0 + k_2 W$$

Case no.	$k_2 \left(= \frac{P - 15}{W} \right)$	Case no.	$k_2 \left(= \frac{P - 15}{W} \right)$
8	2.27	19	2.55
15	1.74	1	2.51
16	2.39	2	1.81
17	1.69	6	2.18
18	1.96	8	1.90

Mean: 2.1

In the sitting position P_0 was 30 kg. *Akerblom* (1949) has shown that in this position the lumbar spine is flexed 30–40 degrees as compared to the standing position. The intrinsic pressure of such a “flexed” lumbar disc was found to be 1.5 kg/cm² or more (*Nachemson* 1962,

1963). In the straight spine of the standing position an intrinsic pressure of about 0.7 kg/cm² was found.

The value for P_0 in standing would be around 15 kg. Using the values in Table 5, obtained from measurements of the intradiscal pressure in the third or fourth lumbar disc in the standing position in 10 individuals, the constant k_2 averaged 2.1 (1.7–2.5) Table 6. Fig. 4.

As was observed in the sitting position the values of P_{standing} are higher than would be expected if gravitational and muscular forces from the erector trunci group alone were responsible for the load on the discs in this position. Also, in most subjects electromyographic studies of the sacro-spinalis muscle group have revealed none or very weak action in this position, (*Floyd & Silver 1955, Portnoy & Morin 1956, Morris et al. 1962*). *Asmussen & Klausen (1962)* in a group of 100 schoolboys found some action potentials in 75 per cent of their material and from the findings they concluded that the line of gravity must pass in front of the lumbar vertebral column by about 1 to 2 cm.

In comparison with the results obtained in the sitting position greater variations are found in the standing position (Figs. 3 and 4). One reason for this could be that the same standing position is more difficult to maintain for a longer period of time (*Boman & Jalavisto 1953*).

The few data presented in Table 3 can be treated as was shown on page 321.

$$(4) \quad P_{\text{standing}} = P_0 + k_2W + k_3 \sin \alpha$$

Solving for k_3 will give the following values: 3.8, 3.7, (case no 6); 3.4, 3.3, 3.7 (case no 8), mean: 3.6.

The mean values of the constants in eq. (4) obtained from the present material:

$$P_0 = 15 \text{ kg}$$

$$k_2 = 2.1$$

$$k_3 = 3.6$$

SUMMARY

The effect of forward leaning of 10 and 20 degrees on the intradiscal pressure in the sitting position was measured in eight individuals. In addition in six of the patients the increase resulting from holding 10 and 20 kg weights in the hands was noted. In two patients the same investigations were made in the standing position as well.

Forward leaning of 20 degrees resulted in an increased intradiscal pressure, and in an increased load on the disc. The increase averaged 30 per cent. Values between 13 and 18 kg/cm² were recorded which implies that the third or fourth lumbar disc has to carry a load of 180 to 230 kg in this position. When carrying weights of 10 kg in each hand the load on these discs was between 250 and 340 kg.

In the standing position the increase of the disc pressure seemed to be proportionally of the same magnitude. The maximal value recorded in the forward leaning position of 20 degrees and carrying 10 kg in each hand was 19.7 kg/cm², corresponding to a load of 280 kg.

From these results it is possible to give relationships between the total load on the disc on one hand, and the position and the body weight above the disc measured on the other hand. The increase in pressure (and load) that occurs on forward leaning is approximately proportional both to sine for the angle of forward leaning and to the total weight above the level measured.

RESUME

L'effet du penchement en avant de 10 et de 20 degrés sur la pression intradiscale en position assise a été mesuré chez 8 individus. De plus, chez six des malades on a noté le résultat du port dans les mains d'un poids de 10 et de 20 kg. Chez deux malades ces investigations ont été pratiquées également en position debout.

Le penchement en avant de 20 degrés provoque une pression intradiscale accrue et une charge accrue sur les disques. La moyenne de l'augmentation est de 30 pour cent. Des valeurs entre 13 et 18 kg/cm² ont été enregistrées, ce qui signifie que le 3ème ou 4ème disque lombaire doit porter un poids de 180 à 230 kg dans cette position. Lorsqu'il est porté des poids de 10 kg dans chaque main, la charge sur les disques est entre 250 et 340 kg.

En position verticale, l'élévation de la pression sur le disque semble être proportionnellement de la même grandeur. La valeur maximum enregistrée dans la position penchée en avant de 20 degrés et le port de 10 kg dans chaque main a été de 19.7 kg/cm², correspondant à une charge de 280 kg.

De ces résultats, il est possible d'établir un rapport entre la charge totale sur le disque, d'un côté, et la position et le poids du corps au-dessus du disque mesuré, de l'autre côté. L'augmentation de la pression (et de la charge) qui se produit dans la position penchée en avant est

à peu près proportionnelle à la fois au sinus de l'angle du penchement en avant et au poids total au-dessus du niveau mesuré.

ZUSAMMENFASSUNG

Die Wirkung eines 10 und 20 gradigen Vorwärtslehns in sitzender Stellung auf den intradiskalen Druck wurde an acht Personen gemessen. Zusätzlich wurde bei sechs der Patienten die Druckzunahme, die entstand wenn sie 10 bis 20 Kg Gewicht in den Händen hielten beobachtet. Bei zwei Patienten wurden die gleichen Untersuchungen auch in stehender Stellung vorgenommen.

Vorwärtslehnen von 20 Graden ergab eine Zunahme des intradiskalen Druckes und eine stärkere Belastung der Zwischenwirbelscheibe. Die Zunahme betrug durchschnittlich 30 Prozent. Werte zwischen 13 bis 18 Kg/Cm² wurden aufgezeichnet. Das bedeutet, dass die dritte und vierte Lendenscheibe eine Last von 180 bis 230 Kg in dieser Stellung zu tragen hat. Wenn 10 Kg Gewichte in jeder Hand getragen wurden, war die Belastung dieser Scheiben zwischen 250 bis 340 Kg.

In stehender Stellung schien die Zunahme des Scheibendruckes proportional von derselben Grösse zu sein. Der grösste aufgezeichnete Wert bei einer nachvorwärts lehenden Stellung von 20 Graden und einem Gewicht von 10 Kg in jeder Hand war 19,7 Kg/Cm², was einer Belastung von 280 Kg entspricht.

Gemäss dieser Ergebnisse ist es möglich die Beziehungen einerseits zwischen totaler Belastung der Zwischenscheibe und andererseits Körperhaltung und Körpergewicht oberhalb der Scheibe, anzugeben. Die Druck- (und Belastungs) zunahme, die beim Vorwärtslehnen entsteht, ist ungefähr proportional sowohl der Grösse des Winkels beim Vorwärtsbeugen als auch dem Gesamtgewicht über dem gemessenen Niveau.

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