Tabulation of the Forces on the Lumbosacral Disc due to Bending and Lifting Positions.

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ABSTRACT

The forces on the lumbosacral disc resulting from the practice of bending and lifting have been calculated. The resultant force was found to depend mainly on the person's weight and the bending angle in the bending situation. For the lifting position, in addition to the person's weight, the resultant force also depends on the trunk dimensions, the angle the trunk makes with the horizontal, θ , and the load needed to be lifted. During bending and lifting it was found that the highest force on the lumbosacral disc is when the trunk is tilted with an angle θ in the vicinity to 10°. During lifting, with the trunk at an angle 10°, the force on the lumbosacral disc reaches six times that of the body weight (assumed 100kg) and the load (assumed 100kg) together. However, during free bending with the same angle the force on the lumbosacral disc reaches 3.5 times that of the body weight.

The concept of the torque can be utilized to act as a guard for the humans in a way that it can protect one of their skeletal parts which is the lumbosacral disc. Several textbooks written for medical students[1,2,3,4] have dealt with such a topic. When bending, the trunk making an angle θ with the horizontal as in Fig. 1, the muscles most involved are the erector spinae which provide the resultant contractive force E. It was found[1] that at this bending position the reaction force R on the lumbosacral disc is greater than the weight of the body by three times when bending at angle 30° and the superincumbent weight W_s is sixty percent of the total weight W. The concentration or the strain

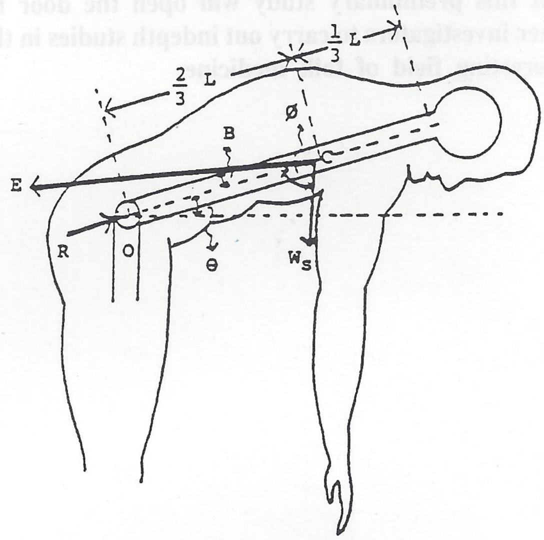

Figure 1 Forces on the vertebral column during bending.

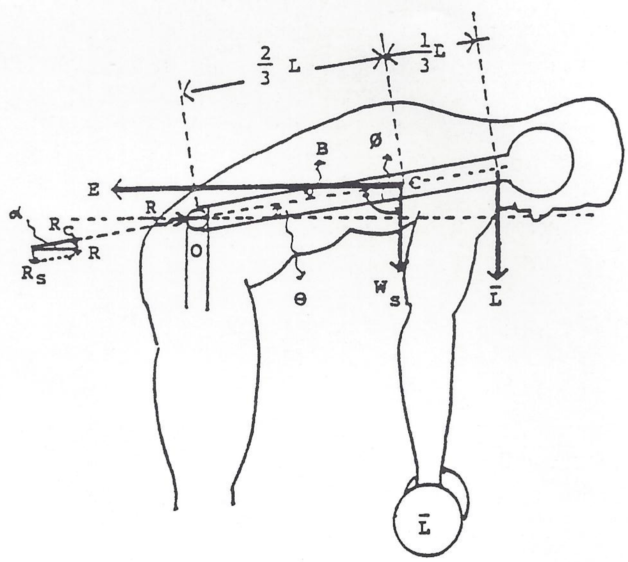

Figure 2 Forces on the vertebral column during lifting.

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resulting from this force was found to be 20%. The situation is rather more serious when lifting with a bad posture as in Fig. 2. Such a comparison between the two situations for different trunk tiltation angles, weight of the body and the load to be lifted will be provided in this paper. This can be done by the aid of using a computer where the results will be useful in a way that it provides a knowledge of what is the maximum weight one can lift so that damage to the lumbosacral disc can be avoided.

METHODS

In order to calculate the resultant force on the lumbosacral disc for bending and lifting situations the following equations were used:

For bending situation

$$R = E \cos B + W_s \cos \quad (1)$$

For lifting situation

$$R = \{ (E \cos B + W_s \cos \emptyset + L \cos \emptyset)^2 + (E \sin B - W_s \sin \emptyset - L \sin \emptyset)^2\} \quad (2)$$

$$\text{i.e. } R = \{ R_c^2 + R_s^2\} \quad (3)$$

where E is the resultant contractive force of the erector spinae muscles acting on the vertebral column, B is the angle between E and the vertebral column line and is taken to be 10° (Fig 1), θ is equal to $90 - \theta$, W_s is equal to 0.6W, L is the load to be lifted in units of Newton, R_c is the compressive component force and R_s is the shear component force in Newton.

RESULTS

Outcome of equations (1) and (2) is listed in tables 1 and 2. The values of θ, the body weight in Kg W, the supercumbent weight W_s in Newton, E, the mass to be lifted M, R_c, R_s and R are listed in these tables.

DISCUSSION

Table 1 indicates that when a person bends his trunk so that it makes an angle of θ in the vicinity of 10°, the force on the lumbosacral disc reaches a maximum value. An overweight person is subjected to more damage than a thin person if he bends his trunk at the same angle θ. For example, if a person A weighs 50kg and a person B weighs 100kg and both A and B freely bend their trunks so that they make an angle 0°, i.e., capital Gamma shape (Γ), then the force on the lumbosacral disc of B will be 3335 Newton and of A only 1667. This means that the force on the lumbosacral disc of B is larger by a factor of 2 than A. The other conclusion from table 1 is that the force on the lumbosacral disc is 82.3% less on standing vertically (θ = 90°) than bending at shape (θ = 0).

TABLE 1

Summary of the calculation of the contractive E and reaction force R during free bending with different angles θ for persons of different body weight W.

θ	W(Kg)	W(N)	W_s(N)	E(N)	R(N)
0	50	490	294	1693	1667
0	100	980	588	3386	3335
40	50	490	294	1297	1466
40	100	980	588	2494	2933
90	50	490	294	0	294
90	100	980	588	0	588

Table 2 which deals with the lifting situation indicates that if someone bends and lifts a heavy object he is most likely to damage his lumbosacral disc. Of course an overweight person will suffer more pain as can be understood from equation two and illustrated by stars in table 2. More stars indicate experiencing the lumbosacral disc with a force in the vicinity to the stage of plastic deformation (end of elasticity or beginning of deformation). For example, a person weighing 50kg and lifting a load of 20kg while bending his trunk at an angle of 10° will subject his lumbosacral disc to a force of 3387 Newton. However, if he was to lift 100kg at the same position then the force would be 10168 Newton which is 3 times larger. Meanwhile, if this person weighs 100kg instead of 50kg then in lifting an object weighing 20kg at the same trunk position as before the force on the lumbosacral disc will be 5080 Newton (instead of 3387 Newton as in the case of the person weighing 50kg) which is 2.33 times larger. Therefore, it is

TABLE 2

Summary of the calculation of the contractive E and reaction force R and its component R_c and R_s during lifting masses M while bending the trunk with different angles θ for persons of different body weight W.

θ	W (Kg)	M (Kg)	E(N)	R_c(N)	R_s(N)	R(N)
0	50	20	3408	3359	219	3366
0	100	20	5113	5035	104	5036
0	50	100	10226	10071	501	10083
0	100	100	11930	11749	503	11750
10	50	20	3352	3386	99	3387*
10	100	20	5019	5079	99	5080**
10	50	100	10088	10156	497	10168***
10	100	100	11756	11849	497	11866***
40	50	20	2607	2882	77	2883*
40	100	20	3904	4349	77	4349*
40	50	100	7847	8547	387	8556**
40	100	100	9144	10013	387	10021***
90	50	40	0	490	0	490
90	100	20	0	784	0	784
90	50	100	0	1274	0	1274
90	100	100	0	1568	0	1568

understood that lifting the same mass but with doubling the person's weight, the force on the lumbosacral disc will be increased by a factor of approximately 1.2 times in lifting a heavy mass and increased by 1.5 times in lifting a lighter mass. Also by lifting objects with a vertical trunk (i.e. by bending the knees) reduces the force on the lumbosacral disc remarkably, approximately by 7.6 times (less by 86.8%).

It is interesting to note that in the vicinity of angle of 10° the highest force on the lumbosacral disc in both lifting and free bending situations is recorded, whereas below this angle and beyond the resultant force on the lumbosacral disc decreases. However, the highest constructive force of the erector spinae muscle during bending and lifting is when θ is equal 0°.

CONCLUSION

Lifting weights with the trunk in a bend position, i.e., low angles will result in a torque of the spinae column and accordingly a considerable force on the lumbosacral disc will result. The situation is more serious if the person is overweight. Therefore, it is recommended to lift weights by bending the knees rather than the trunk. In the free bending situation, which is usual practice during physical exercise, special consideration should be given to overweight people and they should not be asked to bend their trunk at low angles. The minimum recommended angle should not be less than 45°.

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