THE RISK OF WEIGHT-TRAINING AND WEIGHT-LIFTING IN YOUNG PEOPLE

FUNCTIONAL ANATOMY OF THE SPINE

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Although there are known hazards to the spine which arise during heavy manual work, there is little first-hand evidence of back injuries associated with olympic weight-lifting and weight-training in young people. Certainly the incidence of back injuries is probably low when the lifts are performed with skill or under supervision. However, the young are likely to be relatively unskilled and are apt to try heavy lifts in the absence of trained instructors. Theoretically, this presents a variety of dangers when they fail to lift successfully, either because they become temporarily stuck or because they lose control.

The known risks to the spine from heavy manual work can be divided into short and long term effects. In the short term back injuries are exceedingly common; back muscles are pulled, spinal ligaments strained, fractures occur and discs can be ruptured. In the docks, 28% of all injuries affect the back. When heavy work is repetitive long term hazards may arise. Those engaged in heavy manual work are more prone to spinal degeneration than sedentary workers, the onset of bony changes being accelerated (Lawrence, 1969). This does not appear to apply to skilled and experienced weight-lifters (Hult, 1954), but what concerns this meeting now, is the potential dangers to the unskilled and to the inexperienced.

In order to illustrate the theoretical dangers to the spine which arise during weight-lifting, three lifting situations will be analysed:-

- 1) when holding a weight against gravity in the stooping position;
- 2) when an unsuccessful attempt is made to perform the 'press';
- 3) when holding weights vertically overhead with the lumbar spine extended.

It is helpful to begin by considering these situations as static. The analysis can later be modified in accordance with the relevant dynamic factors.

At the beginning of a stooping lift (Fig. 1) the trunk is flexed towards the horizontal and the spine is also relatively flexed in the thoracic and lumbar regions. It should be noted that even when fully flexed the lumbar region is relatively straight and the surfaces of the lumbar vertebral bodies are more or less parallel. There may be a small degree of concavity anteriorly which is sometimes marginally increased at the beginning of a lift (Davis, Troup & Burnard, 1965), but the curve is a minor one compared with the lumbar curve when fully extended.

Figure 1 Stooping posture showing the flexed position of the spine, and the thoracic and abdominal cavities separated by the diaphragm. Note that the lumbar region is relatively straight in the flexed posture.

Figure 2 The position of the 4th and 5th lumbar vertebrae and the sacrum in the stooping posture. Note that the superior articular facets of L5 are resisting a downward vertical force from L4 and that the inferior facets of L5 transmit a vertical force resisted by the sacrum, producing a shearing effect on the pars interarticularis.

Fig.2 illustrates the relative postures of the 4th and 5th lumbar vertebrae and the sacrum in the stooping posture. Considering the effect of gravity on the upper part of the body and on any load handled, there will be a force applied by the inferior articular facets of L4 vertically downwards on the superior articular facets of L5, and by the inferior articular facets of L5 on the articular facets of the sacrum. Therefore there is a marked shearing stress resisted by the isthmus or pars interarticularis of successive vertebrae, in the regions of the vertebral arch between the superior and inferior facets.

There are also other stresses which have to be considered if equilibrium is to be maintained. In Fig.3 the tension transmitted by the muscles and tendons of the erector spinae group is represented by the force 'F'. This is balanced by the force 'C' which is equal and opposite to 'F', and which tends to compress the vertebral bodies and discs. Thus 'F' and 'C' together form a mechanical couple. Some idea of their magnitude while stooping and holding a load can be given if the combined weight of the upper part of the body (say 35kg) and of the load (50 kg) represents a total mass of 85 kg. The horizontal distance of this

$$W.x = F.d$$

Figure 3 Diagram illustrating the extensor force 'F' transmitted by the post-vertebral muscles and the compressive force 'C' resisted by the vertebral bodies and discs induced by the effect of gravity on the upper body and the load lifted in the stooping posture. Vertical acceleration of the weight increases the magnitude of 'F' and 'C'.

combined mass from the L4/5 disc is not likely to be less than 5 x the distance between the forces 'F' and 'C', which are therefore unlikely to be less than 425 kg. in magnitude. However, in static situations which the unskilled may undergo, this is close to the maximal compressive forces which the vertebral bodies can resist for the strength of the vertebral body is inversely related to the duration of the force applied (Perey, 1957). The situation also becomes more dangerous if the spine is twisted or rotated when withstanding such compressive loads (Roaf, 1960).

Figure 4 Theoretical force 'P' which when applied to the situation illustrated in Fig.3 would tend to reduce the magnitude of 'F' and 'C' for a given force 'W'.

It would therefore be a good thing if an additional force 'P' could be applied as in Fig. 4, as this would reduce the magnitude of 'F' and 'C' for a given force 'W'. In fact, this appears to be the role of increased intra-truncal pressures. Pressures in the thoracic and abdominal cavities are generally increased on exertion by closing the glottis, or, if pressures are raised only in the abdominal cavity, by diaphragmatic activity, and contracting the muscles of the pelvic floor and the transversely oriented fibres of the abdominal muscles. This makes the trunk more rigid and the pressure tends to expand the cavities. However, expansion can only take place anteriorly, separating the rib cage from the pubis and so extending the spine (see Fig. 5.)

Figure 5 Stooping figure with force diagram to illustrate the effect of increased intra-abdominal pressure which tends to separate the rib cage anteriorly from the pubis. The effect is to extend the spine, or resist further flexion and so reduce the forces 'F' and 'C'.

Thus, physiologically the effect of the increased pressure can be represented by the force 'P'. If intra-abdominal pressure is monitored, the magnitude of the increases at the beginning of a lift is related to the speed with which a given weight is raised (Davis, 1959,) and it is related to the magnitude of the weight lifted (Davis 1959 b; Morris, Lucas & Bresler, 1961; Davis & Troup, 1964, 1966). Studies using the force platform indicated that the magnitude of increases in intra-abdominal pressure were related to the stresses induced in the spine and trunk (Davis, Whitney, Troup & Gear, 1964). Thus, although there are marked potential dangers in stooping to lift, particularly when performed slowly, the ability to increase the intra-truncal pressures is a safeguard at any rate as far as the spine is concerned.

In the press the situation is entirely different. The principal dangers there arise from contravention of the rules which disallow "exaggerated lean-back". Unfortunately this occurred repeatedly at the British Schoolboys Weight Lifting Championship which took place at Oxford on 4th October, 1969. In one case, the lifter became stuck in the posture illustrated in Fig. 6 for a period of not less than 1 second: thereby justifying a static analysis.

Figure 6 Tracing from photograph of 16 year old with "exaggerated lean-back" during the 'press'. The force diagram superimposed indicates:-
 'W' the weight of the barbell (82.5kg.) and of the upper part of his body (27.5kg) = total 110 kg.
 'S' the force parallel to the L2/3 disc tending to displace L2 posteriorly on L3 = 97.5 kg.
 'F' the resultant force normal to the line through the L2/3 disc = 51 kg.
 'A' the force transmitted by the abdominal muscles to balance 'F' = 121 kg.
 'C' the compressive force on the L2/3 disc = 172 kg.

The barbell weighed 82.5 kg. and this combined with the weight of the upper part of his body resulted in a force 'S' parallel to the lumbar 2/3 disc, of the order of 100 kg. This force tends to displace L2 posteriorly on L3 resulting in shearing stresses resisted by the disc and tensile stresses involving the interspinous ligament and the capsules of the synovial joints (Fig. 7). There are no muscles which are in positions to act directly to reduce these stresses. If the lifter loses control and twists at this stage the resulting lateral displacements between vertebral bodies may well produce damage, and ligaments may be ruptured.

Figure 7 The 2nd and 3rd lumbar vertebrae in the posture taken from Fig. 6 in which the force 'S' of 97.5 kg. tends to displace L2 posteriorly on L3. This is resisted principally by the disc, the interspinous ligament and the capsules of the synovial joints.

Figure 8 The posture of the 3rd, 4th and 5th lumbar vertebrae and the sacrum in subjects standing erect with a lordosed spine. In addition to the force tending to displace L5 anteriorly on the sacrum there are also considerable shearing forces resisted by the pars interarticularis of L5.

The third situation illustrating dangers in weight-lifting is that in which weights are held vertically overhead on the completion of the lift. It was very common at the Schoolboys Championships to see postures in which there was a marked lordosis, the lumbar posture being almost fully extended. In this situation the lumbar vertebrae are arranged as in Fig. 8, and there is a tendency for L5 to be displaced vertically downwards, or anteriorly in relation to the sacrum which is more or less horizontal. Again there is a considerable stress in the pars interarticularis of the vertebral arch where stress fractures are not uncommon.

Taking these potential dangers into account it would be relevant to consider what proportion of the population exposed to weight-lifting is in fact fit to do so. In industry, particularly in the USA, it is not uncommon to screen recruits in order to exclude those with spinal defects from jobs involving heavy work. In such pre-employment examinations which include x-rays, up to 25% of the total have been considered unfit for heavy work (Runge, 1954; McGill, 1968). In a study of 16 - 20 year old police recruits in Germany, Ross (1962) listed the incidence of the defects which were revealed radiologically (see Table). With the exception of cases of spondylolisthesis, few of these defects by themselves contra-indicate heavy work. However, spondylolisthesis and other cases in which there were defects of the pars interarticularis accounted for a total of 10.1% in a series of 29,000 examinations of men with apparently normal backs reported by Moreton (1969). It is therefore likely that at least 1 out of every 10 boys who try their hands at weight-lifting should be discouraged.

Table

Percentage incidence of radiological defects in 16-20 year old males (Ross, 1962)

	Cervical	Thoracic	Lumbar
Irregularities of vertebral body surface (including Scheuermann's disease)	60%	15.5%	63.2%
Schmorl's nodes	9%	6.3%	39.2%
Narrowed intervertebral discs	12%	0.8%	10.3%
Erosion of vertebral body margin	18%	3.6%	22.5%
Wedging of vertebral body	10%	5.0%	10.3%
Osteophytosis	12%	5.0%	17.7%
Spondylolisthesis	24%	-	3.4%
Total number of subjects examined	100	2,623	2,408

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