A STUDY OF A TRAMPOLINE EXERCISE BY SYNCHRONIZED CINEPHOTOGRAPHY INTRA-TRUNCAL BAROMETRY, ELECTROCARDIOGRAPHY AND ELECTROMYOGRAPHY

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This study was concerned with the abdominal and spinal activity during somersaulting and other exercises on the trampoline. During such exercises there are many interrelated factors which if analysed in a skilled performer can contribute to a new understanding of training methods. There are many difficulties in recording several biological parameters simultaneously during gymnastic activities but to achieve an accurate analysis of an exercise it is essential to synchronize the relevant parameters. The present study extends our earlier work, Bevan & Corser, 1969 and Corser and Thomas, 1970 by including intra-truncal barometry and electro-cardiography. These parameters permit a correlation of the exercise with important changes in intra-truncal pressure and the activity of the heart.

METHODS

The records were of four types:

(1) 16 mm. cinephotography was linked by a frame synchroniser to a signal marker on an eight channel pen-oscillograph. The camera was set up 5 metres from the performer to allow full coverage of the exercise.

(2) Intra-truncal barometry was obtained by using a radio pressure pill calibrated to emit a change of frequency linearly from 0-200 mm.Hg. pressure. The radio-pill (in a suitable thin rubber envelope) was swallowed two hours before the exercise. The radio-receiver input was connected to an aerial worn as a belt by the performer, the output was connected to a channel of the pen oscillograph.

(3a) Electrocardiography was obtained from trailing wires from two 1.5 cm. silver disc electrodes placed 2.5 cm. apart immediately inferior to the bulk of the pectoralis muscles and in line with the left nipple. These electrodes were attached to the skin by standard 3M double surfaced adhesive discs. Good electrical contact was achieved by local skin abrasion and filling the electrode cavity with saline electrode jelly. The cardiogram was a direct record using the amplifier and a channel of the pen oscillograph.

(3b) For a part of the study it was necessary to have a heart-rate analysis of the exercise. This was made with a pulse telemeter connected to an electrode disc placed on the superior aspect of the sternum and another placed inferior to the left pectoralis muscles 5 cm. lateral to the nipple line. This arrangement allowed freedom from trailing wires and by connecting the receiver to a standard electrocardigraph a permanent and accurate record was obtained.

(4) Electromyography of the exercise as a group muscle analysis of the skill was impracticable in this study which was limited by the number of recording channels available. Five muscles were chosen after preliminary trials to determine those which most obviously might be of interest to the study. As a result the phasing in time of the muscles being active has been of greater importance than differences in magnitude of activity between them. Therefore we have not included calibration scales on these traces. The technique of electrode attachment, signal amplification and recording were identical with what has been described for electrocardiography. For each muscle the electrodes were placed about 2.5 cm. apart on the belly of the muscle; the sites are given in Fig. 5.

The connexions for the various recordings were gathered in a single cable about 3 metres in length between the belt and a fishing rod and thence to the pen-oscillograph. This permitted the performer to be "played" - rather like a fish on a line - during the exercise, without damaging the leads.

INTERPRETATION OF MYOGRAMS

In preliminary studies we have found that with less skilled performers there are much bigger differences between the electromyograms in successive repetitions. Therefore we suggest that to achieve reliability, electromyographic analysis of complex movements must be based upon several repetitions of the same movement. When recording from highly skilled performers the repetitions approach identity.

The traces shown in Figs. 1 and 2 are typical of a series of repeated exercises of which only these are reproduced. In Fig. 2 can be seen a massive action potential of the rectus abdominis at take off followed by complete silence in mid-flight and finally a short burst of activity in the descending phase of the movement. The massive contracting phase, which actually begins prior to take off in both Figs. 1 and 2. coincides with the performers effort to lift the buttocks upwards and backwards whilst still in contact with the trampoline bed and thus gain rotational momentum without 'travel'. In Fig. 2 the period of silence coincides with the phase of the movement when the performer grasps his shins and therefore requires no abdominal tension to resist the centrifugal force which otherwise could tend to extend the hips and spinal joints. The shorter, moderate burst of activity during the descending phase of the movement is a postural contribution by the rectus abdominis to the controlled extension of spine and hips into landing position.

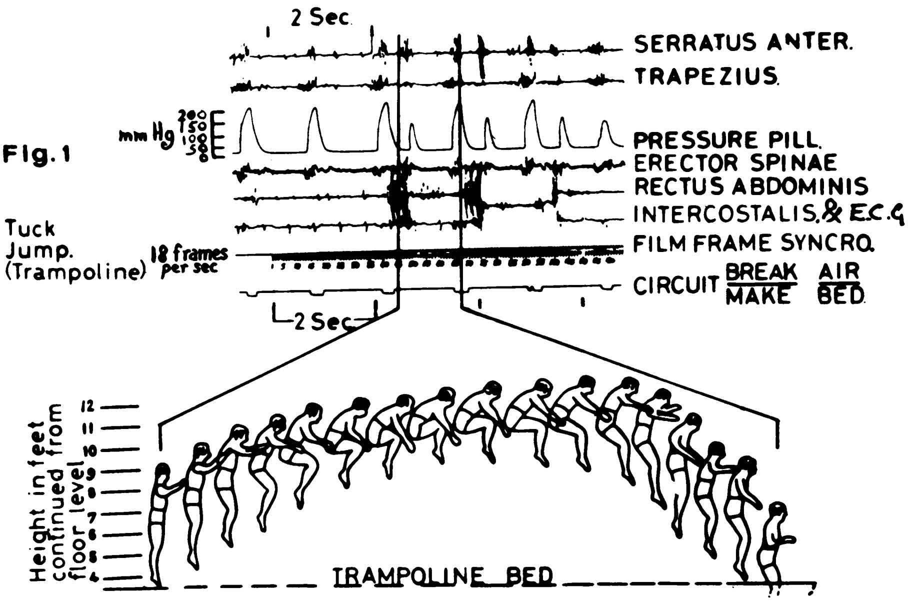

Fig. 1

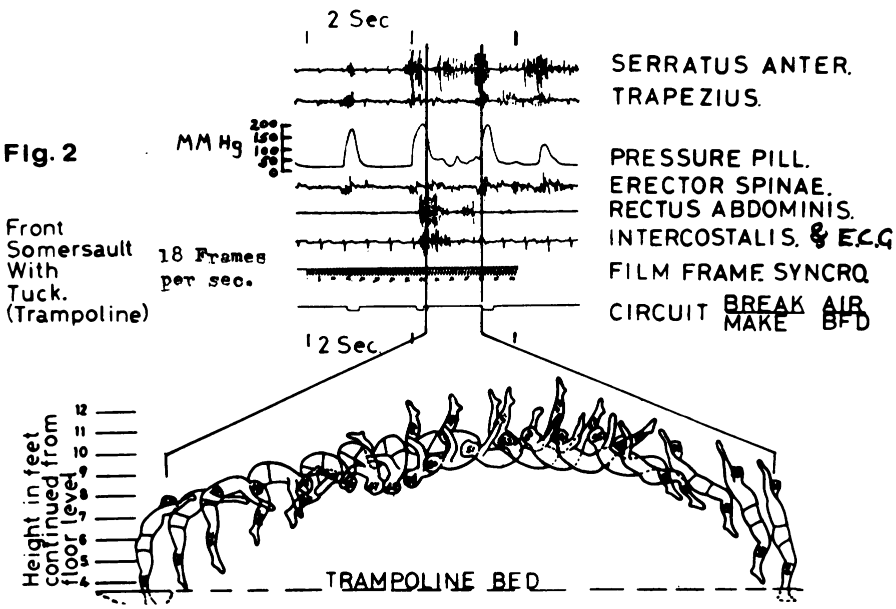

Fig. 2

The onset of this abdominal activity preceded hip and spinal flexion, indicating that the muscle had to exert tone to control the abdominal contents before contributing to the movement. From the intra-abdominal pressure records, it can be seen that during take off for the somersault (Fig. 2), the gut was compressed and tended to displace the lower abdominal wall. In this situation it was probable that before the rectus abdominis exerted effective tension to relocate the front of the pelvis to allow hip flexion and assist flexion of the lumbar vertebrae, it has had to constrain the abdominal contents. Floyd and Silver (1951) and later Ono.(1958) found that the rectus abdominis was silent during 'bearing down' whether the subject was recumbent or erect, but neither of these studies involved such vigorous movements as the 'somersault exercise'.

In such exercises, the postural action of the rectus abdominis controlling extension of the spine and hips is critical in timing and effect. The action of the trapezius can be seen to have coincided with this in the extension of the arms. In the somersault the arms controlled rotational velocity of the body, adjusting its moment of inertia about a horizontal axis. If this had not occurred correctly, the subject would not have landed in a balanced standing position. Analogous hip and spine flexions and extensions are to be found in many other gymnastic movements involving considerable angular momentum (Bevan & Corser 1969), and it is likely that the rectus abdominis plays a similar important role in these movements. Certainly the same pattern of rectus abdominis activity is found in the "back somersault with tuck, head forward" (Fig. 3). As before, the essential two bursts of action potential occurred, albeit at a higher amplitude. It is of interest to note that the performer was aware subjectively of an increased, sustained abdominal tension in this type of somersault in spite of the 'tuck' position being of shorter duration. The intra-abdominal pressure trace confirmed this. A very similar analysis is possible of this exercise performed with the "head back" (Fig. 4.) The new requirement obviously involved greater initial activity from the muscle. In the 'tuck' jump (Fig. 1) there was no second burst of abdominal action because there was no rotational momentum of the whole body to counteract while controlling balance.

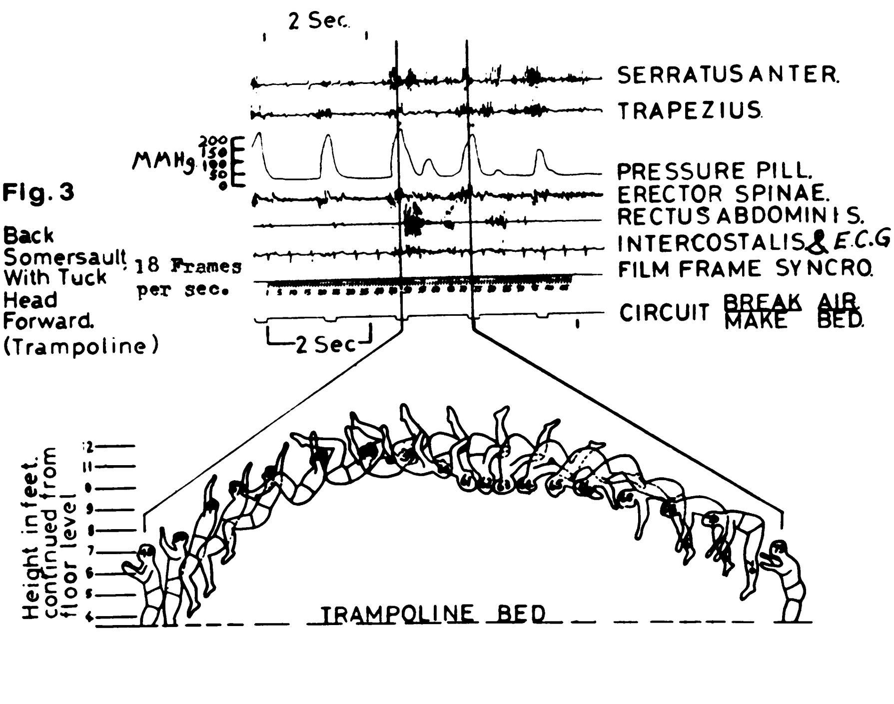

Fig. 3 Back Somersault With Tuck Head Forward. (Trampoline)

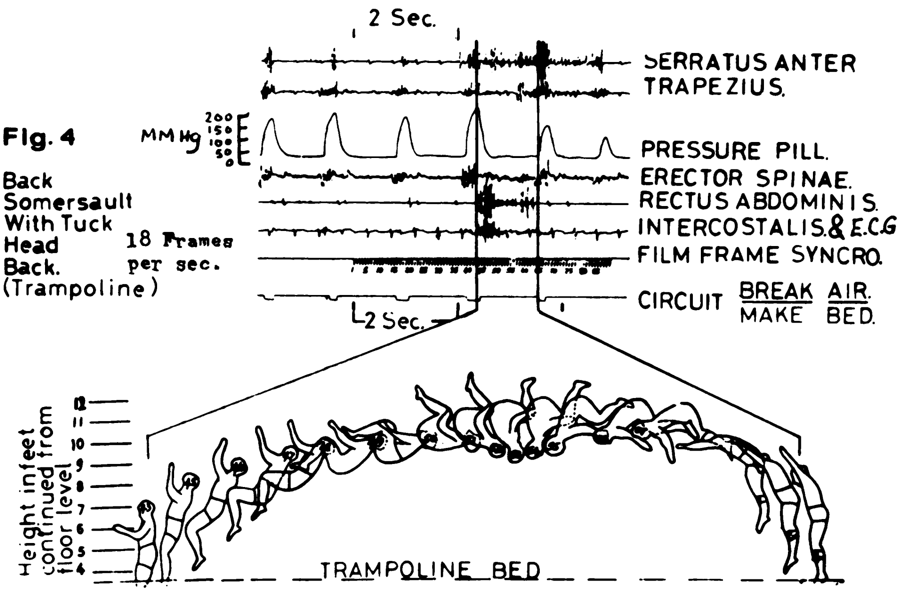

Fig. 4 Back Somersault With Tuck Head Back. (Trampoline)

In these exercises, analysis of rectus abdominis activity is most rewarding, and the other four muscles merit briefer treatment. Unfortunatly, it was not possible to do a full group muscle analysis and these muscles were chosen as the most likely to give myograms directly related to that of the rectus abdominis. It can be seen that at the point where its main activity occurred, the intercostalis was also active, probably as fixator of the lower ribs while the rectus abdominis exerted its pull. Obviously little costal fixation was needed for postural purposes. However, all the exercises showed that while the rectus abdominis is generally relaxed during stronger activity of the erector spinae, the converse was not found. The erector spinae was active throughout all the movements, as is to be expected with its action as a prime postural muscle.

The serratus anterior and the trapezius both gave strong bursts of activity during the arm raising movements which occurred in both take-off and landing phases of the exercises. This was compatible with the accepted actions of these two muscles, but in these exercises the arms were used only to preserve symmetry in the air and no simple repetitive movement occurred other than the obvious effort to aid 'lift' which showed clearly in the myogram.

ELECTROCARDIOGRAPHY

No significant changes in pulse rate were obtained during the performances of one trampoline movement. An average standing resting pulse rate 88 beats/min. rose to 122 during the few preliminary bounces and then rose to a maximum of 145-173 after the movement had finished. During a ten bounce routine (including preliminary bounces) a typical pulse rate reaction was:-

Start ↓ Stop ↓

ACTIVITY	BEFORE BOUNCING	Ten bounce		EXERCISE				Recovery while standing								
TIME (Sec.)	0	5	10	15	20	25	28	30	35	40	45	50	55	60	65	70
PULSE RATE beats/min.	88	105	132	153	167	173	176	176	174	170	168	166	162	157	146	165

During continuous bouncing to exhaustion, pulse rates taken every 5 seconds were as follows:-

Start bouncing (5 sec. intv.) 128, 142, 168, 180, 182, 184, 170* (1 missed beat) 188, 188, 190, 188, 190, 190, 190, 188, 190, 190, 190, 186, 188, 188, 189, 189, 187, 190, 190 - exhaustion.' (at 135 sec.)

Recovery (5 sec.intv.) 188, 187, 185, 184, 178, 174, 169, 164, 158, 152, 146, 141 (end of 1 minute).

This demonstrates that trampolining involves very high energy cost in terms of cardiac activity. It may be that an unskilled performer allowed to exercise to exhaustion would run serious risk of injury due to fatigue and consequent loss of co-ordination. The use of a spotting rig would reduce this resk during trampoline training for endurance. In the subject in our study, the electrocardiogram demonstrated little or no cardiac intolerance. This type of non-clinical electrocardiography would seem to be a reliable procedure even in such energetic physical activities. Movement artefacts were avoided by approximating the two electrodes so that certain components of the 'classical' wave form were lost, but in the majority of such investigations the same electrodes can duplicate with a muscle location as has been done in this study. As a control in endurance training, telemetred e.c.g. would give useful freedom to the performer.

INTRA-ABDOMINAL BAROMETRY

In this study the recordings have in fact been of intra-abdominal pressures (i.a.p.) obtained by telemetry. Fig. 5 shows tha i.a.p. transmitter aerial belt positions and the elctromyograph electrode sites. In trampolining a high level of skill depends on the effective control and utilisation of the performer's internal anatomy as well as external environment.

(1) I.A.P during contact with trampoline bed

The gross build-up of i.a.p. produced by the tendency of the intestines to compress downwards in the abdomen whilst the torso is decelerated is well illustrated in all the traces.

In order to control, utilise and re-distribute the forces generated by the interaction of trampoline and performer, a reflex mechanism of trunk muscle contraction was induced. The traces indicate that the level of i.a.p. and muscle activity predetermine and are proportional to the height of subsequent bounce. The rise in i.a.p. during deceleration illustrated its role in relieving the compressing forces to which the spinal column would otherwise be subject.

(2) I.A.P. during flight

In Fig. 1 the i.a.p. rise whilst airborne denotes constriction of the abdomen.

In Fig. 2 the sustained activity of rectus abdominis after leaving the trampoline caused a retention of high i.a.p. until the inversion of the subject at Frame 47. The rise in pressure at Frame 52 coincided with the onset of activity designed to bring the performer out of the 'tucked' position.

In Fig. 3 the rise in pressure at Frame 54 was coincident with the beginning of the 'tuck movement'. Failure to show such reaction in the 'head back' attempt (Fig. 4) would seem to indicate a major overall postural difference determined by head position in this type of exercise. Perhaps this was manifested by a less marked flexion of the spinal column which in some way limited the degree of assistance required from i.a.p.

Summary and Conclusions

1. Interest in this study was mainly focused upon flexion and extension of hips and spine involved in somersaulting. The 'tuck' jump was included because of its relationship with this type of somersault and it enabled us to compare movement in this position with no lateral or asymmetrical rotation.

2. The muscles followed a similar action to that already described in many kinesiological references: the serratus anterior and trapezius muscles were active during arm action, causing scapular rotation, and the intercostalis acted as a fixator of the lower ribs during activity by the rectus abdominis.

3. Although it is possible to make comparisons between different electromyograms of the same exercise by the same performer, to achieve reliability, electromyographic analysis of complex movement must be based upon repetitive recordings of the same exercise.

4. Analysis of the electrocardiogram demonstrated that trampolining involves very high energy cost in terms of cardiac activity and that at extreme levels of exhaustion an unskilled performer might run serious risk of injury due to fatigue and consequent loss of co-ordination.

5. The rise in intra-abdominal pressure during deceleration illustrates its relieving role on the compressive forces to which the spinal column would otherwise be subjected. It also played a vital role in determining the degree of postural rigidity needed to transfer propulsion from the trampoline to the next airborne phase.

6. Cinephotographic synchronization is essential for interpretation of electromyograms dealing with complex dynamic movements quite apart from its use in segmental analysis and for reference value in intra-abdominal pressure studies.

References:

Bevan, J.G.R. and Corser, T. 'The biomechanical Study of Gymnastic Movement'. The Gymnast, March 1969.

Corser, T. and Thomas, V. 'The kinesiological uses of electromyography synchronized with cinematography'. J. Physical Ed., in press.

Floyd, W.F. and Silver, P.H.S. (1951). 'Electromyographic study of patterns of activity of the anterior abdominal wall muscles in man'. J. Anatomy, 84: pp. 132 - 145.

Hamley, E.J. and Saunders, G.R. (1969). 'The contributions of trunk musculature to intra-abdominal pressure changes'. J. Physiol., 200: pp. 96 - 98P.

Ono K. (1958). 'Electromyographic studies of the abdominal wall muscles in visceroptosis. 1. Analysis patterns of activity of the abdominal wall muscles in normal adults'. Tohoku J. Exper. Med., 68: pp. 347-354.

Rasch, P.J. and Burke, R.K. 'Kinesiology and Applied Anatomy - The Science of Human Movement'.