SCOLIOSIS

PLASTIC CHANGES IN SPINAL FUNCTION OF PRE-PUBESCENT SCOLIOTIC CHILDREN ENGAGED IN AN EXERCISE THERAPY PROGRAMME

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ABSTRACT

Previous studies (Stone *et al.*, 1979) of the effect of exercise therapy on scoliosis have demonstrated progression of spinal curves despite vigorous exercise regimens. This study presents evidence to the contrary.

Ten South African black school children with mild scoliosis and attendant upper thoracic asymmetries were analysed both before and after a specific exercise therapy programme, in order to determine the effect of the therapy on spinal functionality and the scoliotic curve. The effect of this intensive treatment, in which the subjects underwent a five-month exercise training programme with a total of 60 one-hour sessions, was investigated in a controlled clinical trial.

A subjective and objective appraisal of posterior trunk asymmetry in school-children aged 7 – 18 years is reported. Selected functional and anthropometric measurements were made before and after the treatment, and antero-posterior X-rays were used to indicate changes in the scoliotic curve. New methods are described for quantifying the scoliotic curves in each child.

Post-treatment tests showed a significant (p) decrease in Cobb's angles as well as a significant reduction in all the spinal and thoracic functional asymmetries observed in the study.

The findings suggest that selective exercise programmes can contribute to improvement in cases of functional scoliosis. The study sheds new light on problems related to scoliosis and the benefits of exercise rehabilitation.

Data on the incidence of scoliosis amongst 1052 black children are presented and discussed too.

INTRODUCTION

Previous studies have tended to demonstrate that in cases of functional scoliosis, postural muscle "tightness" should be assessed during musculo-skeletal examinations, and that the treatment rationale should include appropriate mobilisation therapy along with improving imbalances between antagonistic muscle groups along the spine (Janda, 1983; Alter, 1988; Nudelman and Reis, 1990). However, no published data were found on the effect of these treatments on lateral deviations of the spine.

This study was designed to determine whether or not it is possible to show reduction of the lateral deviation in a group of functional scoliotic children following a 20 week period of therapeutic exercises, and to examine the extent to which spinal function can be improved.

METHOD

Ten scoliotic school-children (mean age 10.6 years) were examined and measured by one trained observer via the following stages:

Subjective assessment

The presence or absence of the following bodily symmetries was recorded:

- Shoulder height
- Scapular level
- Chest and hip prominence
- Lateral deviation of the spine.

The child was then asked to bend forward looking at the floor, keeping the feet together, knees braced back, shoulders loose and hands positioned between the knees. A subjective assessment of asymmetry of the upper chest, mid-chest and lower chest, the lumbar region and sacrum was made in this position. The presence of absence or a lateral spinal curvature (clinical evidence of scoliosis) was recorded.

Objective assessment

At this stage data were collected in the following categories:

Demographic data: Including age, mass, stature and family history of scoliosis, as well as medical, surgical and developmental history.

Anthropometric measurements: The anthropometric parameters chosen were those that have a functional role in the general aims of the clinical examination, and were aimed at observing any lateral symmetries along the body. The following measurements were made, all within tolerance limits of 5 mm:

- Height of acromia: The vertical distance from each acromion to the floor.
- Scapula-spine distance: measured horizontally from the inferior angle of each scapula to the nearest vertebral thoracic spinous process.
- Biacromial diameter: The maximum distance between right and left acromia, measured from behind with the subject standing. The pointer was brought down onto each acromion from above.
- S1 - Acromia distance: The distance between right and left acromia to S1 with the subject standing.
- Height of anterior superior iliac spines (ASIS): The vertical distance from each ASIS to the floor.
- Lower limb length: Measured from the ASIS to the medial malleolus, with subject lying supine.

In order to be able to compare different symmetries at different sites on the same scale, an asymmetry ratio (AR) was derived as follows:

AR = H/L-1

Where: H = higher shoulder height, and L = lower shoulder height.

Thus, all data were recorded as positive values. For each subject AR was calculated for selected anthropometric measurements.

Functional measurements:

- Trunk flexion (thoracolumbar spine): The distance between the spinous processes of C7 and S1 in the start position with the subject standing, and at the limit of motion with the subject flexing the trunk forward.
- Lateral bending test: Measurement of distance between C7 and seating plane with the subject sitting erect and at limit of motion with the subject bending laterally to the right and left sides. The pelvis was stabilised to the plane of the seat.
- Spinal rotation: Rotation angle of the spine (cervical spine excluded) with the subject sitting and at the limit of motion with the subject rotating the spine to the right and left sides.

The pelvis was stabilised and a pointer was connected to the sternum to measure angular movement.

- Shoulder flexibility: Both shoulder joint and shoulder girdle flexibility was examined. Test position: the right elbow was raised and the right hand reached down between the shoulders with the subject sitting erect. The left hand was placed in the small of the back with the fingers pointing upward and the palm facing away from the back. The distance between the hands if not overlapped or the amount of fingers overlap was measured.
- Hamstring flexibility: Measurement of the angle of straight leg raising in a supine position, with the lower extremities extended.

Scapular asymmetry: The angle of acromial plane scapular asymmetry was determined using linear distance between the acromia (h) and the vertical difference in acromial height measured from the floor (o) as depicted in Figure 1. Thus the angular asymmetry is given by:

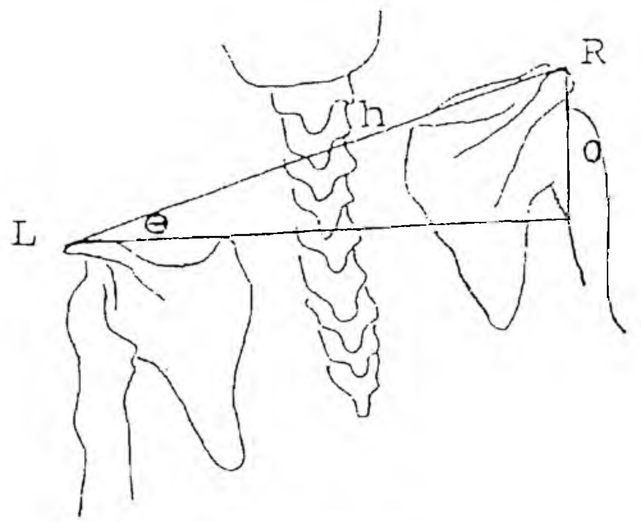

Figure 1: Scapular asymmetry

θ= Arc Sin o/h

Several researchers have reported that the development of a curvature is most likely during periods of rapid growth (Taylor, 1983; Loncar *et al*, 1991). Since the development of scoliosis is so intimately related to the development and growth of the skeleton, physical anthropometry can be an important measurement tool. However, quantifying change of shape, over time, especially as it related to scoliotic progression or response to treatment, is also an important clinical problem. The precision of measurement techniques is crucial to accurate detection of change, especially in the case of back-surface measurement whose magnitude is small compared with the magnitude of the underlying skeletal deformity. One of the major factors limiting the understanding of the relationship between therapeutic physical activity and scoliosis is the lack of easily administered valid and reliable measures, which will obviate false conclusions (Figure 2).

As Figure 2 shows, a taller subject (with presumably broader chest), appears to exhibit a greater asymmetry in terms of disparate heights of left (L) and right (R) acromia, while in fact this may be an artifact of body size. Even if stature is identical, an individual with larger bi-acromial axis may exhibit an apparent (but not real) increase in asymmetry. Thus, in the present study, asymmetry was viewed as an angular deviation which is independent of size, and θ in Figure 2 is identical, despite a considerable apparent difference in left and right acromial height. On the assumption that a subject undergoing an adolescent growth spurt could conceivably grow in stature and/or bi-acromial diameter without in fact changing the relative level of asymmetry, this would convey a spurious impression that the asymmetry had increased when in fact it might even have diminished.

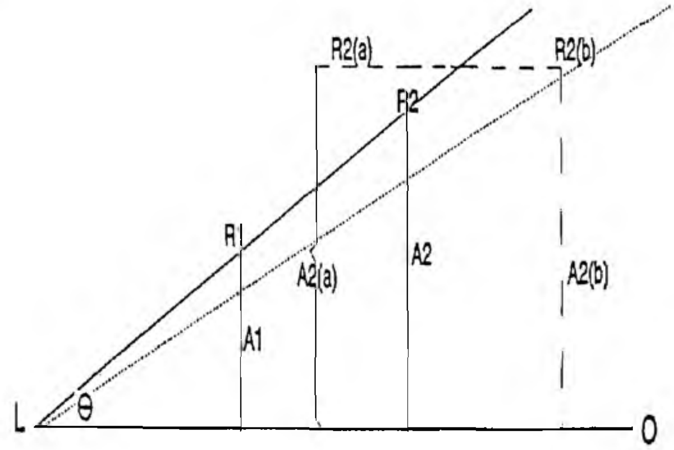

Figure 2: Angle of asymmetry

L–R1: original measure
L–R2: later measure. A2>A1 but θ is constant
L–R2(a): later measure. A2(a)>A1 and θ is increased
L–R2(b): later measure. A2(b)>A1 but θ is decreased.

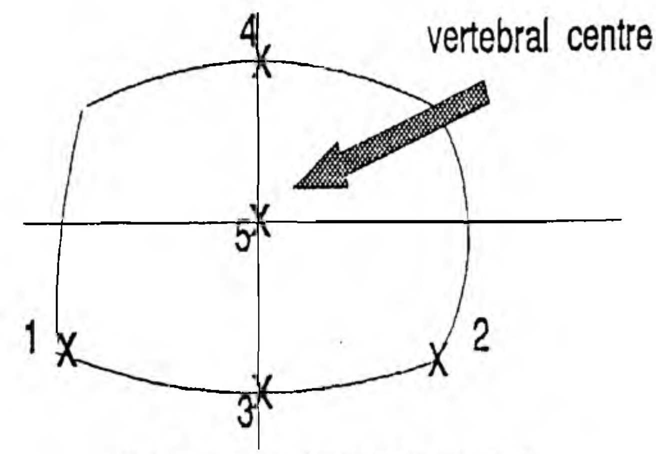

Figure 3: Five anatomincal points on the vertebral body

Thus the angle θ expresses acromial height asymmetry better, as a size-independent measure, and therapeutic interventions are then aimed at reducing θ to zero, while growth changes are factored-out. This will also enable data from different age groups to be pooled for statistical analysis.

Measurements on the Radiographs:

One anteroposterior roentgenogram was taken of each subject in a standing position, using a large 36 x 43 cm cassette and directing the central ray horizontally to the mid-point of the film. The research protocol was approved by the appropriate sub-committee on ethical standards which required, inter-alia, the direct personal involvement of an orthopaedic surgeon during the X-ray phase, to ensure that only children deemed on medical grounds to require X-ray screening would be subjected to this intervention.

These radiographs were analysed using the following measurements:

All spinal curvatures were measured in degrees as described by Cobb (1958.).

Measurements of the general spinal deviation was developed, as follows:

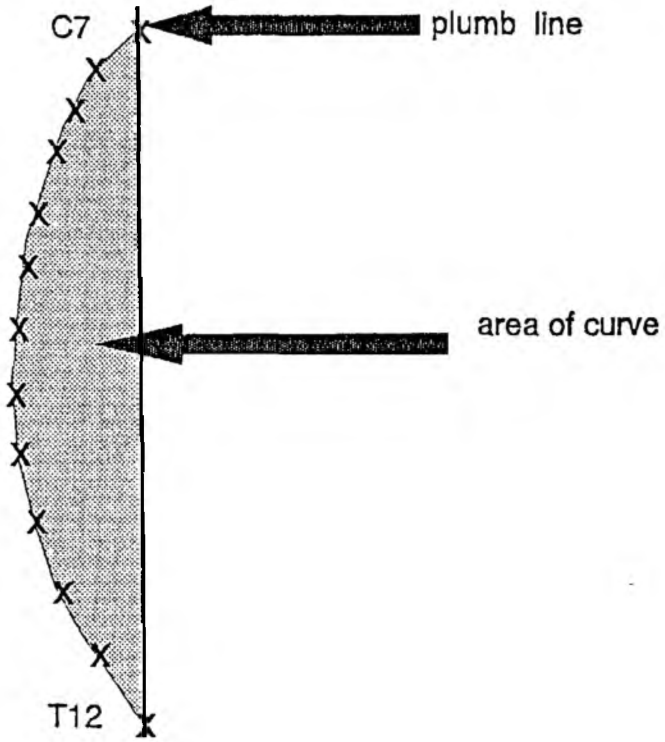

Figure 4: Measurement of area under the curve

- A plumb-line was drawn on the radiograph from the spinous process of C7. In cases of a cervical curve, this line was drawn from the first symmetrical vertebra.
- Five anatomical points were then identified on each vertebral body within the curve (Figure 3), and used to find the middle point of the vertebra.
- The distance between each vertebral centre and the plumb line was measured to the nearest millimetre and the spinal deviation relative to this vertical line was then calculated using a simple ratio relationship:

$SD = \Sigma d/H$

Where SD is the extent of spinal deviation; d is the distance of each vertebrae from the plumb line; and H is the height of the vertebral body of the twelfth thoracic vertebra. This ratio relationship ensures standardisation of the measurement if the child grew in size and/or if projected X-ray image altered from test to test.

The area under the curve was measured, as follows:

- A straight line was drawn between all the vertebral centra within the curve.
- The area under the curve (i.e. between the plumb line and the curve) was measured in square centimetres using a compensating polar planimeter.
- For standardisation of the measurement, this result was divided by the area of the body of T12 as measured on the same X-ray. Thus:

$SRD = C/A$

Where SRD is the size-relative curve amplitude encompassing spinal deviation, C is the area under the curve, and A is the area of the twelfth thoracic vertebra. This ratio relationship was used to ensure standardisation of the measurement.

Treatment

Following examinations and X-rays, the subjects were requested to participate in a 60-treatment exercise therapy programme in which a graduated regime was provided to enhance each subject's muscular strength, neuromuscular coordination and joint range of motion (ROM) according to individual needs. The subjects were seen three times weekly for 20 weeks and a warm, well-lit room was utilised throughout.

Exercise procedures and programme

The aim of the treatment was to provide therapeutic regimens differentiated by each patient's initial functional condition. The treatment was specifically adjusted to the subjects, taking account of the direction and extent of the curve(s). The programme was designed to release muscle contractures on the concave side of the spine, since soft tissue contracture in this area is one of the main forces maintaining the deformity, resisting correction and rejecting implants (Nudelman and Reis, 1990).

The lateral deviation of the spine might also reduce the ability of the intervertebral disc to distribute weight effectively and a decrease in the disc height might occur, causing abnormal weight-bearing by the facet joints and an alteration in facet joint alignment (Cailliet, 1975). Therefore, one of the general aims of treatment was to encourage awareness of the use of the spine in everyday life, and teach the application of mechanical principles of kinetic handling in activities of daily living.

The exercise system and procedures were developed by the author. The exercises were taught to the subject during an orientation session. Before the subjects were allowed to participate in the study, they were required to perform the exercises correctly. Subjects were individually supervised during their exercises to ensure correct execution. A log was kept, recording exercise dosage date in the following categories: intensity, repetition and frequency. Adjustments of exercise intensity were made for exercise progression each month. Treatment sessions were of one hour duration each. During the first two weeks, quality of performance of the exercises was emphasised. In addition to performing exercises during the treatment sessions, the subjects were instructed to do these same exercises at home.

The exercises were of two types. The first consisted of ten exercises and was a standard conditioning routine to maintain the strength of the trunk muscles as well as its normal range of motion. Vigorous exercises included incidental movements that are translated to active correction of the major curve. The second type comprised exercises involving specific movements designed to diminish the curve of the individual in question.

After 20 weeks (60 treatments) subjects were re-evaluated and the initial measurements were compared to post-programme responses. Paired t tests were used to evaluate the effectiveness of the programme in reducing bodily imbalance, improving spinal functionality and altering the Cobb angle as measured on the X-rays.

RESULTS AND DISCUSSION

Pre-treatment Roentgenographic Findings

The criteria for the existence of scoliosis in this study included the presence of obvious truncal lateral symmetries as well as confirmation of those signs in the erect anteroposterior roentgenogram of the spine using as the criterion a minimum of 5°, determined by Cobb's technique.

Anthropometric measurements:

The exercise programme had a positive effect on all the symmetries which were observed in the anthropometric measurements. The general asymmetry scores (E H/L-1) were significantly decreased (p) by the treatment programme.

The programme-effects on Acromial Angle Asymmetry are presented in Table I.

TABLE I: Effects of programme on acromioal angle asymmetry		
Condition	Subject number	Angle of asymmetry
Pre-treatment acramial asymmetry	1	4,3
	2	1,0
	3	3,1
	4	1,9
	5	2,0
	6	2,8
	7	0,1
	8	2,4
	9	4,2
	10	3,1
		$\bar{x}$ 2,4
		SD 1,2
Post-treatment acromial asymmetry	1	1,2
	2	0,0
	3	0,6
	4	0,0
	5	0,0
	6	0,0
	7	0,0
	8	0,0
	9	0,0
	10	0,0
		$\bar{x}$ 0,1
		SD 0,4167

The angle of acromial asymmetry appears to serve not only a good indicator of the need for treatment, but as a quantitative measurement of realignment. A comparison between pre- and post-treatment results show a significant improvement after the exercise programme (Table I).

Functional measurements:

Functional tests were used in this study as a means of the determinating functional limitations of the scoliotic spines and extent of truncal symmetries.

The results of the functional measurements concur with other studies of lateral symmetries, which found that there is a relation between scoliosis and functional imbalances (Nudelman and Reis, 1990; Kisner and Colby, 2985; Thompson, 1989). The majority of the subjects in this study presented with tightness in postural muscles, predominantly those maintaining the locomotor posture, to correlate with the concept that these muscles adaptively shorten and become tight (Janda, 1983).

The treatment apparently exerted a significant influence on all the observed functional symmetries, over the 20-week period of the programme (p).

Results of measurements on the X-ray films:

In roentgenographic examinations, magnification of the image depends on the tube position. A magnification factor was taken into account to standardise this. Because all of the geometric information was compressed onto a single film plane, the magnification varies with the position of the part of the skeleton being measured, since it is also dependent on the distance from the film plane. This may produce small differences on the radiograph and therefore all the measurements on the X-rays in this study were standardised (using T_{12} as a reference vertebra) by the method described earlier, before the data on the spinal deformity could be obtained with confidence.

Cobb Angles:

The results of pre- and post-treatment curves, as measured on the X-rays, show significant reduction in Cobb angles and are presented in Table II.

TABLE II: X-ray results pre/post-treatment curves (Cobb angles)			
Number	Pre-treatment	Post-treatment	% reduction
1	27,0	9,5	64,8
2	12,0	8,0	33,3
3	6,0	6,0	nil
4	7,5	3,0	60,0
5	9,5	5,0	47,3
6	8,0	4,0	50,0
7	7,0	4,0	42,8
8	9,0	5,0	44,4
9	15,0	4,0	73,3
10	9,0	2,0	77,7
	$\bar{x}$ 11,0	$\bar{x}$ 5,05	54,1
	SD 6,2	SD 2,3	SIG

The results of this study show that the area under the curve as well as the general spinal deviation scores were significantly lower in the post-treatment measurements. The significant positive changes in these measurements, and in the Cobb angles give some indication of the success of the training programme. The results seem to confirm the potential value of an intensive and rigorous therapeutic exercise programme in the treatment of scoliosis, and argue against the opinions postulated by Kisner and Colby (1985) and others (Keim, 1982; Roaf, 1958), who consider exercises beneficial only when performed by patients wearing trunk orthoses.

Measurement Procedures

The measurement techniques used in this study have been applied to studying the effects of treatment, as well as to improving our description of the scoliosis deformity and our understanding of its aetiology. The test sequence presented facilitated observation in an ordered way to avoid unnecessary changes in starting positions. This further encouraged efficiency during the tests and was a practical method of evaluating the musculoskeletal system in children. To ensure valid conclusions from the data, the reliability of all the measurements was determined.

The measurements used yielded acceptable test-retest reliability, and can improve the therapist's ability to decide the effectiveness of treatments. In this way modifications of the treatment plan can be initiated at an earlier phase of therapy. The author believes that the methods which were developed in the study are rigorous and would appear to reflect the magnitude of the scoliotic curve. Thus, clinicians should consider using the methods described when evaluating patients with suspected spinal problems.

Exercise programme and treatment procedures:

Treatment of scoliosis by exercise therapy remains controversial, with most of the investigators reporting poor results and questioning its effectiveness (Cobb, 1958; Keim, 1982; Road, 1956; Tarr, 1948; Kisner and Colby, 1985; Stone *et al*, 1979). Most of these authors contend that exercise of any kind is not beneficial in inhibiting scoliotic development. In 1941, the American Orthopaedic Association's Research Committee came to the conclusion, after a study of 425 cases of end-result idiopathic scoliosis, that exercise should be avoided. This study found that approximately

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after a study of 425 cases of end-result idiopathic scoliosis, that exercise should be avoided. This study found that approximately 60% of the patients treated with exercises had an increase in the deformity, and 40% had no change.

Recent work done by Stone *et al* (1979), has included a nine-month exercise therapy programme for 99 subjects with scoliosis and also reported poor results. However, the results of this study showed the extent to which, under the optimal conditions outlined, therapeutic exercises were capable of correcting functional scoliosis and a significant change in both body position and spinal functionality was shown after 20 weeks of treatment. The data revealed post-treatment values that suggested that some positive changes had taken place due to the therapeutic programme. It appears that in cases of lateral symmetries, young children have high potential for balancing the trunk muscles if the exercise intensity is well regulated and monitored. This should encourage clinicians to consider using exercise therapy as an important treatment for functional scoliosis.

Extreme care was taken in the present study to control testing procedures and the conduct of the treatment programme itself. It is admissible, where other outcomes are the focus, to be less rigorous with respect to the treatment itself. Thus Stone *et al* (1979), had subjects perform an active exercise programme at home with no supervision, as opposed to the individual attention given to each subject in the present study. However, it is the author's opinion that without individual supervision, no valid information on the effect of exercise programmes on functional scoliosis can be achieved.

The information presented here is an attempt to show the responses of the functional scoliotic spine to an individualised and closely supervised exercise programme. This knowledge may provide a useful basis for better understanding and management of functional scoliosis, and might shed additional light on the effectiveness of exercise therapy in the treatment of this problem.

REFERENCES

1. Alter M J. *Science of stretching*. First Edition, Illinois: Campaign; 1988:17-21.
2. Cailliet R. *Scoliosis*. First Edition, Philadelphia. F A Davie; 1975:12-43.
3. Cobb J R. Scoliosis. *Journal of Bone and Joint Surgery* 1958;**40**(A):510-512.
4. Janda V. On the concept of postural muscles and posture in man. *Australian Journal of Physiotherapy* 1983;**29**(1):83-85.
5. Keim H R. *The adolescent spine*. First Edition, New York: Springer-Verlag;1983:25-62.
6. Kisner C, Colby L A. *Therapeutic exercise*. Second Edition, Philadelphia: Davis F A;1985:509-542.
7. Loncar D M, Pecina M, Preberg Z. A longitudinal study of growth velocity and development of secondary gender characteristics versus onset of idiopathic scoliosis. *Clinical Orthopaedics* 1991;**270**(1):278-282.
8. Nudelman W, Reis N D. Anatomy of the extrinsic spinal muscles related to the deformity of scoliosis. *Acta Anatomica* 1990;**139**(3):220-225.
9. Roaf R. Paralytic Scoliosis. *Journal of Bone and Joint Surgery* 1956;**38**(b):640-659.
10. Stone B, Beekman C, Hall V *et al*. The effect of an exercise program on change in curve in adolescents with minimal idiopathic scoliosis. *Physical Therapy* 1979;59(6):759-763.
11. Tarr I. Analysis of normal and scoliotic spine. *Physiotherapy* 1948;**28**(1):6-10.
12. Taylor J R. Scoliosis and growth. Patterns of asymmetry in normal vertebral growth. *Acta Orthopaedica Scandinavica* 1983;**54**(1):596-602.
13. Thompson C W. *Manual of structural kinesiology*. Eleventh Edition. Boston; Times Mirror;1989:51-83.

THE SA JOURNAL OF PHYSIOTHERAPY IN THE INTERNATIONAL CONTEXT

■ *by Lo-an Roux, Physiotherapy Publications*

In his last editorial after editing the *New Zealand Journal of Physiotherapy* for nine years, Bryan Paynter comments that on the occasion he "left out the editorial to see if anyone would notice, nobody said a word". He also comments that he is not certain that his wish that the Journal would be a vehicle of professional communication was fulfilled to the extent he desired.

And yet the index of articles in the December issue of the *New Zealand Journal of Physiotherapy* looks interesting enough:

- Study raises concern about concussion in rugby league games
- Neural involvement in shoulder pain
- Hypertrophy and hyperplasia in skeletal muscle following endurance training
- The effects of ultrasound on tumour growth and metastasis
- Physiotherapists rated positively by parents
- Overweight nurses suffer more back pain
- Clinical notes
- Working in the USA – a Kiwi perspective
- New directions for physiotherapy research.

Kathy Henderson is the Scientific Editor of the Australian Journal of Physiotherapy, and in her December editorial "Careful manuscript preparation maximises publication potential" she comments that "the majority of manuscripts are returned to the author(s) for revision" and that "a number of manuscripts require revision on more than one occasion prior to acceptance for publication".

And yet the index of articles indicates that Australian physiotherapists are writing scientifically acceptable articles:

- Effect of trunk flexion speed on flexion relaxation of erector spinae
- Effect of age, gender and speed on three dimensional lumbar spine kinematics
- Group exercises for subjects with osteoarthritis of the knee
- Post stroke recovery of balanced sitting and ambulation ability
- Does laser enhance bruising in acute sporting injuries:
- Physiotherapy management of obstructed defaecation
- How to write a paper for a scientific journal.

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