THE RELATIONSHIP OF THE HEIGHT OF THE LONGITUDINAL ARCH OF THE FOOT TO THE ALIGNMENT OF BODY SEGMENTS AND SELECTED MOTOR PERFORMANCE MEASURES

by

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B.Sc., University of Oregon, 1978

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in the Faculty

of

Education

We accept this thesis as conforming
to the required standard

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August 1979

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ABSTRACT

The purpose of the study was to determine whether Grade One boys, grouped according to the height of the longitudinal arch of the foot, significantly differed on the variables of: power; balance; flexibility; the height of the thoracic curve; the depth of lumbar curve; and foot alignment. Eighty-five subjects ranging from six years and seven months to seven years and four months were divided into three groups based on the height of the longitudinal arch. A one way analysis of variance was used to determine if significant differences existed between the groups, and a multivariate discriminate function analysis was implemented to determine the best predictor for the height of the arch. Results showed that only for flexibility was there a significant difference between the groups, and that flexibility provided a more effective predictor than any combination of variables in determining the height of the arch.

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ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my adviser, Dr. Bruce Howe, for his considerate and helpful counsel during this work. His openness and knowledgeable guidance during my graduate study contributed to an invaluable experience.

My thanks also go to Dr. I. MacRae, Dr. J. Eckerson, and Dr. R. Ruth for their assistance as members of the Supervisory Committee, and to Dr. J. McLeish and Dr. N. Gleadow for their expert advice. Finally, I would like to thank the Principals and staffs of the five schools in the Greater Victoria School District that were used for my data collection. They were as follows:

(1) Richmond Elementary;

(2) Campus View Elementary;

(3) Gordon Head Elementary;

(4) Monterey Elementary; and

(5) Hillcrest Elementary.

CHAPTER 1

INTRODUCTION

Context of the Problem

From the beginning of the twentieth century, misalignment of body segments, including poor posture, has been the subject of numerous unsubstantiated claims related to health. For example, Deaver (1933) found that poor posture had been blamed for such circumstances as prolapse of the stomach, constipation, sagging bowels, and the fall of nations. In contrast, good posture had been praised for its indication of physical efficiency, character, and intelligence. Subsequently, several researchers such as DiGiovannas (1931), Top and Alden (1931), Spindler (1931), Cyriax (1936), Fox (1951), Moriarity and Irwin (1952), Flint and Diehl (1954), Davies (1957), Coppock (1958), Flint (1963, 1964), and Hutchins (1965), sought to determine the importance of good posture and its relationship to human performance. Despite these studies there has been a decreasing interest in this area by physical educators. Fox (1959: 315) reported that an examination

of *Research Quarterly* showed 33 articles were published under the rubric of "posture" between 1930 and 1939 but only four articles in the following decade. Clarke (1979), in a more recent review, found only 11 articles on this topic in the past 29 years had been published in the *Research Quarterly*. Nevertheless the increase in exercise programmes for adults has again stimulated interest in problems of body alignment.

Within the general topic of body posture, the lowering of the longitudinal arch of the foot has also been a target for unproven theories and conflicting opinions with regard to its cause, effects and treatment. Harris (1925) stated that:

> The symptoms of flat foot fatigue are protean. They range from headache, eye symptoms excessive to lesions found; backache, pelvic, inguinal, and genito-urinary pains, sciatica, and of course, leg and foot pains and aches.

This condition, medically described as pes planus, is the most common form of flat foot and has also been termed "acquired or static flat foot" by Ochsner (1907), "weak feet" by Boorstein (1925), "actual or potential flat foot" by Rochm (1933), "hypermobile flat foot" by Alicandri and Kelly (1963), "flexible flat foot" by Connolly, Regen and Hillman (1970), and "postural flat foot" by Sherrill

(1976: 115). In contrast to pes planus, these authors agree that the second form termed "congenital" or "rigid flat foot" is a rare and more serious condition with a poor prognosis for successful treatment. "Rigid flat foot" will not be considered in this study.

Despite the considerable literature in this area, to be reviewed in Chapter II, several questions regarding the relationships of flexible flat foot and certain physical and performance variables remain unanswered, especially with regard to younger children. Shands (1964), Walker (1972), Sherrard (1976), Paul (1976), and Scougal (1977) noted the specific age of six years as an important time for diagnosing and treating foot anomalies. They claimed that by that age the child's "fatty-pad" underneath the foot would have disappeared, making abnormalities of the arch easier to identify. Further, Alicandri and Kelly (1963) after reporting the results of a screening programme conducted on Canadian soldiers, mentioned that similar studies were needed to be performed on subjects in younger age groups. Whether Grade One children with a lower than normal arch are adversely effected in the variables of balance and power is not known. Nor is it known whether Grade One children with a lower than normal arch will possess anomalies in overall body segment

alignment. Finally little research is available to determine whether the fallen arch is more flexible than a normal arch.

Statement of the Problem

The purpose of this study was to determine:

(a) whether Grade One boys with a lower than normal arch differ from Grade One boys with a normal arch on variables of power, balance, flexibility, the thoracic curve, the lumbar curve, and foot alignment;

(b) whether Grade One boys with a normal arch differ from Grade One boys with a higher than normal arch on variables of power, balance, flexbility, the thoracic curve, the lumbar curve, and foot alignment; and

(c) whether Grade One boys with a higher than normal arch differ from Grade One boys with a lower than normal arch on variables of power, balance, flexibility, the thoracic curve, the lumbar curve, and foot alignment.

CHAPTER II

RELATED LITERATURE

The longitudinal arch extends from the heel to the ball of the foot and is comprised of two separate arches: the lateral arch, which is situated along the outer border of the foot; and the medial arch, which runs along the inner border of the foot (Arnheim, Auxter, and Crowe, 1977: 201-203).

Risser (1955), and Lake (1937) stated that the longitudinal arch served to protect the nerves, blood vessels, and muscles of the foot. Arnheim, Auxter and Crowe (1977: 244) agreed with these authors, and also included the absorption of shock from weight bearing as another of it's important functions. Richardson (1930: 97) said that the purpose of the longitudinal arch was "to give spring and resilience to the body, and to prevent repeated jarring."

The Development of the Longitudinal Arch

There are conflicting opinions about the structure of the arch in the newly born infant. Boorstein (1925), Dykes (1963), Sherrill (1976: 115), and Fixen (1976)

claimed that the neonate had no arch, and Shands (1964) agreed with these previous authors and stated that the longitudinal arch developed when the infant began to walk.

Conversely, Lewin (1926), Lake (1937), Giannestras (1970), and Scougal (1977) firmly stated that the infant was born with an arch. Giannestras used X-ray to support his theory, and Lake claimed:

> Some authorities say that the infant's foot has no arch until postural tonus develops. But this is pure fiction. The baby's foot has a wonderful arch, but it is concealed by a thick pad of fat.

Causes of Flexible Flat Foot

Authors that attempted to explain the lowering of the arch can be separated into: those concerned with environmental factors; and those concerned with deviations in the anatomical construct.

Environmental factors. The earlier authors of the twentieth century such as Boorstein (1925), Lewin (1926), and Roehm (1933) looked toward infectious diseases as the most prevalent cause in the flattening of the arch. Ramsey, cited by Roehm (1933), considered that 90 per cent of flat foot was due to infection found in other parts of the body. Ehrenfried (1914) examined the medical histories of 55 cases of flexible flat foot and discovered 147 disease

occurrences, of which the most common were measles, whooping cough, and chicken pox.

Another supposedly causative agent for the collapsed arch was the use of high-heeled shoes. Richardson (1930: 98), Mayo-Collier cited by Whitman (1888), Fait (1978: 370), and Hook and Hooley (1976: 228) all considered that wearing high-heels was an element that accentuated the weakening and falling of the arch. Richardson stated that, "man's skeleton was not made to be perched on heels," and was supported by Sheehan (1973) who claimed that shoe design controlled bodily posture. Despite these claims, this investigator could find no data on incidence in females as compared to males.

In addition, Richardson (1930) and Herzmark (1963) blamed flat, hard, unyielding surfaces found in urbanized areas as a further cause of flat foot. Herzmark declared that these surfaces offered no challenge for the development of foot muscles, and so the everted heel and the pronated foot of the normal infant would possibly last throughout life.

Deviations in the anatomical construct. Today, authors such as Connolly, Regen and Hillman (1970), Sherrard (1976), Scougal (1977), and Fait (1978: 369) have proposed that abnormalities in the anatomical make up are the major

cause of flexible flat foot. Kite (1956), Dykes (1963), and Vanden Brink (1976) claimed that this irregularity had been discovered in children who had continually slept in the prone position, with the legs in the "frog-like" angle and the feet turned out at 90 degrees. They explained that this created lateral rotation of the legs which carried over when the child began to walk. Hence, the feet would pronate and the arch would collapse.

Most authors have agreed that the lowering of the arch was due either to lateral rotation, the everted heel (calcaneo-valgus), a shortened achilles tendon, or ligamentous laxity (Harris and Beath, 1948; Risser, 1955; Omer, 1963; Alicandri and Kelly, 1963; Giannestras, 1970; Fixen, 1976; Vanden Brink, 1976; and Paul, 1976). However, Roehm (1933), Dykes (1963), and Menelaus (1969) discussed the possibility that the anatomical anomalies which created the condition might have been genetically determined.

Ochsner (1907) and Lewin (1926) also considered the onset of puberty as a factor in the falling of the arch. Lewin mentioned that there was a definite form of weak, pronated, or flat foot that appeared at the time of the adolescent growth spurt, and Fox (1959: 323) said that pronated feet were relatively common in teenagers who did not complain of foot discomfort.

The assumption that intrinsically weak foot muscles initiated the collapsing of the arch was proposed by Whitman (1888), Ehrenfried (1914), and Lewin (1926), but studies by Hicks (1955) and Basmajian and Stecko (1963) reported that the muscles of the foot responsed only to heavy loading, such as the take-off phase in walking.

Techniques for Evaluating The Height of the Longitudinal Arch

One of the earliest methods of examining the height of the arch was devised by Lowman, Colestock, and Cooper (1928: 231-2), who suggested tracing around the foot to identify the amount of pronation that existed in the foot and ankle. The sand box technique, as described by Cureton (1935), calculated the height of the arch by measuring the depth of the foot print depression in wet sand. However, Danford (1935) took a slightly different approach and determined the degree of ankle pronation by the alignment of the Tendon Achilles. He devised a glass pedorule that was able to measure how far this tendon deviated from the straight position. Arnheim, Auxter, and Crowe (1977: 478) described and illustrated two other methods, both of which showed the structure of the longitudinal arch in the weight-bearing condition. Firstly, the podiascope, which was used to observe the sole of the foot

by means of a glass standing platform above an angled mirror, and secondly the pedograph, invented by Dr. Scholl, which provided a permanent, recordable outline of the sole of the foot by means of an inked impression. Clarke (1933) and Cureton (1935) formulated ways to determine the height of the longitudinal arch that could be used on the inked impression and both authors obtained reliability correlations of .90 or above.

Subjective methods of analyzing the arch, such as the New York Posture Rating Chart, cited by Fait (1978: 372), and Hwang's procedure, cited by Cureton (1935), used nominal categories to rate the severity or mildness of the flat foot condition. Both methods were devised for mass screening programmes where time was a limiting factor.

Incidences of Flat Feet

Albert, cited by Ochsner (1907), reported that out of 17,619 surgical cases at the Munich Surgical Polyclinic, 1.9 per cent suffered from flat foot, which was second to scoliosis as the most common deformity.

Harris and Beath (1948) discovered that out of 3,619 Canadian soldiers examined during 1944 and 1945, 716 or 87.8 per cent of the 815 cases of flat foot were of the mild or moderate condition. Greenberg et al (1959) found

that from 1,845 students screened in School District No. 30, Valley Stream, New York, as many as 33 per cent of the students had a mild foot pronation. Cronis and Russell (1965) reported from the Delaware Orthopaedic Screening Project, that 20 per cent of the 921 children in the final examination were considered to have pes planus, which was almost twice as much as the second most common anomaly, knock knees. Of these 20 per cent, 4.8 per cent went for surgical consultation, 2.1 per cent were sent for X-ray, 35.8 per cent were given corrective shoes, 0.5 per cent were given special exercises, 1.1 per cent were asked to return for a recheck in one to two years, while 55 per cent were given no treatment at all. Shands (1964) reported that from 4,230 children examined at the Alfred I du Pont Institute, 1,232 received a diagnosis related to the foot, and 63.6 per cent were considered to have pes planus. Finally, Shapiro and Rhee (1970) discovered that out of 8,995 kindergarten and pre-school children screened in the District of Columbia, 2,632 or 29.2 per cent had flexible flat foot, but only 654 or 24.8 per cent needed treatment. The screening programme was to be continued.

Concomitant Effects of Flexible Flat Foot

The idea that flexible flat foot was a disability that required special attention, was conceived before the twentieth century. Munson, cited by Ochsner (1907), reported that 33 out of 9,901 members of the Illinois National Guard were denied entry into the United States service in 1898 because of excessive flat foot, and Ochsner found that during the years 1903, 1904, and 1905, 457 out of 132,145 men were excluded from the United States Army for the same reason. Herzmark (1963) reported that the disability suffered most by enlisters during World Wars I and II was related to weak, painful, flat feet.

Consequently, over the past eighty years, statements with regard to the detrimental effects of the lowering of the arch have been numerous. Bancroft (1913: 98), Boorstein (1925), Lewin (1926), Richardson (1930: 97), Alicandri and Kelly (1963), Funk (1967), and Connolly, Regen, and Hillman (1970) claimed that flexible flat foot could lead to one or more of the following variables: aching calf muscles; night cramps; fatigue; and pain. Boorstein, Lewin, Funk, and Harris and Beath (1948) also mentioned that a child with this condition would not want to play running games and would avoid strenuous activity.

These five authors along with Ehrenfried (1914), Roehm (1933), and Herzmark (1963)used the word "weak" synonymously with the term flat foot, and in his opening paragraph Herzmark stated:

> Weak or flat feet in children is a serious problem and is engaging the attention of physicians and parents more and more because of the increasing incidence and the disabilities and limitations it evokes during the adolescent and adult years.

Increased range of motion. This irregularity caused by laxed ligaments or the widening of the joints between the bones, has been a widely accepted concomitant of flexible flat foot (Roehm, 1933; Harris and Beath, 1948; Kite, 1956; Funk, 1967; Connolly, Regen, and Hillman, 1970; Walker, 1972; Preston, 1974; Paul, 1976; Vanden Brink, 1976; and Scougal, 1977). Hence, the terms "supple", "flexible", "hypermobile", "relaxed", and "hyperlaxed", all have been used to describe the effects of the fallen arch.

Toeing-out. Ochsner (1907) reported that of all the patients suffering from flat feet that he had observed, not one stood or walked with his feet nearly parallel. Whitman (1888), Lewin (1926), Richardson (1930: 97), Risser (1955), Omer (1963), Connolly, Regen and Hillman (1970), Preston (1974), and Sherrill (1976: 115) asserted that

an abnormal toeing-out position accompanied the fallen arch. Helfet (1956) referred to this anomaly as the "Charlie Chaplin gait", and Kite (1956) said that when one foot points east, the other points west. Bancroft (1913: 100) stated that the only proper way to walk was in the straight-foot position, as it

> is the one in which the Indians perform their great endurance feats of running and walking, and it is also characteristic of our best athletic runners. In this position the foot has its greatest elasticity and can bear the weight the longest without fatigue.

Studies on the Longitudinal Arch and Performance

Cureton (1935) used 600 college athletes, over a period of five years, to study the relationships between the height of the longitudinal arch and performance on foot skills. He found low and insignificant correlations with each of the variables of vertical jumping, speed running over 50 yards, 440 yard running, and lifting strength tests. Further, Cureton cited Greunberg, who also had found insignificant relationships between the height of the longitudinal arch and foot strength, ankle flexibility, and balance. In his conclusion Cureton stated:

> The tremendously large number of defective feet reported throughout the literature is probably an exaggeration due to all persons with low arches, as measured by footprints, being classed as defective. Men have probably been

> excluded from the army and children put in corrective classes who had the strongest feet.

Kelly (1947) studied the structure and functioning of the feet of three groups of children. The first group (n = 75) were considered to have symptomless, normal, well aligned feet and legs. The second group (n = 52) were considered to have symptomless, weak or pronated feet, and the third group (n = 51) were reported to have suffered from functional foot strain. Her results supported claims of an increased range of motion accompanying the lowering of the arch, as she found a low positive significant correlation between pronation and flexibility of the arch. However, she also reported, in contrast to the majority of claims in the literature, that toeing-out was negatively correlated with pronation, and that out-toeing angles of 14 to 20 degrees between both feet were characteristic of both normal and pronated feet.

Treatment Methods

Funk (1967) aptly stated that no other condition had been so widely misunderstood, overtreated, or overlooked, and this investigator found that the different approaches to treatment, if needed, depended entirely upon the author's attitude toward the severity, or mildness, of the flat foot anomaly. Dykes (1963), Shands (1964), Funk (1967),

Menelaus (1969), and Walker (1972), acknowledged that the longitudinal arch developed when the child began to walk, run, and play, and that for the majority of infants the flat footed structure spontaneously regressed with time. Fixen (1976) felt that large numbers of children had been treated unnecessarily, and along with Sherrard (1976) claimed that the reason why most treatment methods were considered successful was because the condition naturally corrected itself. In support of this theory, Morley (1957) discovered that at 18 months, 97 per cent of the 1000 children that he had examined were considered to have flat feet, but by ten and 11 years this number was reduced to four per cent.

Whitman (1888), Harris and Beath (1948), and Preston (1974) divided cases of flat foot into three categories: mild, moderate, and severe. Each of the investigators stated that the longitudinal arch in the mild condition did not have to be touching the ground, and Bleck (1971) asserted that the appearance of a low arch did not justify the diagnosis of flat foot.

The most prevalent method of treatment for the mild, and moderate forms has been the corrective or orthopaedic shoe (Boorstein, 1925; Roehm, 1933; Risser, 1955; Kite, 156; Dykes, 1963; Alicandri and Kelly, 1963; Funk, 1967; and

Connolly, Regen and Hillman, 1970). However, Fixen (1976) and Menelaus (1969) stated that orthopaedic shoes would not change the shape of the foot. Walker (1972) and Preston (1974) took an even more moderate view and said that there was no need for any treatment in the milder cases of flexible flat foot.

Conversely, Ehrenfried (1914), Omer (1963), and Herzmark (1963) declared that treatment should begin as early as possible, even for the milder conditions. In agreement with this, Giannestras (1970) said:

> The past thinking that correction of this deformity is spontaneous as the infant grows old is fallacious. Unfortunately, it persists even among orthopedists. If the child has flat feet at birth, he will always have flat feet.

He suggested that the theory of spontaneous regression be disregarded, and the infant placed in corrective casts from four to six months, followed by a pair of Whitman steel arch supports, before the final stage where corrective shoes are worn, and the arches replaced every nine months. Similarly, Herzmark (1963) reported good results from infants whose feet were placed in plaster boots.

Another widely advocated form of treatment is the use of ameliorative exercises, games, or activities such as barefoot walking. These are designed to strengthen weak muscles, and build a stronger, healthier arch (Ochsner,

1907; Bancroft, 1913: 99; Boorstein, 1925; Richardson, 1930; Harris and Beath, 1948; Omer, 1963; Dykes, 1963; Shands, 1964; Sherrill, 1976: 116; Arnheim, Auxter and Crowe, 1977: 204; and Fait, 1978: 370). However, contrary to this belief Scougal (1977) and Sherrard (1976) stated that foot exercises designed to strengthen supposedly weak muscles provide no value in the treatment of flexible flat foot. In fact, Scougal went as far as to say that the only value they had was to keep anxious parents occupied when nothing else satisfied them.

Summary

Based on the readings presented in this review of literature, the following statements seem to be applicable:

1. The longitudinal arch is shaped to provide for the absorption of shock from weight-bearing, and protection of the more delicate parts of the foot.
2. There are conflicting opinions as to whether the longitudinal arch is present at birth or develops in time through exercise.
3. During the first few decades of the twentieth century, debilitation through disease was considered to be the major cause of the lowering of the arch.

4. Today, individual anatomical anomalies are considered to be the most prevalent cause of flexible flat foot.
5. There are opposing views with regard to: the seriousness of the flat foot condition; the age at which treatment should be started; the type of treatment; and the advantages and disadvantages of certain methods of treatment.
6. Little scientific research has been used to study the effects of flexible flat foot upon performance.
7. The results of the screening programmes would suggest that the high incidences of flat foot require further investigation.

CHAPTER III

RESEARCH METHODS

Subjects

All grade one boys were tested from five selected schools of the Greater Victoria School District. Of this group, 85 were selected with an age range from six years and seven months to seven years and four months, which is a ten month difference. Schools were chosen as representative of the total school district population.

Independent Variable

The height of the longitudinal arch of the foot. All subjects were administered the pedograph screening test as developed by Scholl (Arnheim, Auxter and Crowe, 1977: 478-480). From the pedograph's ink foot-prints, the height of the longitudinal arch of the right foot was found by calculating the angle at which the medial arch joined with the base of the metatarsals, as described by Clarke (1933):

> 1. Draw line "A" to represent the medial border of the foot between the points of the imprint at the base of the first metatarsal bone (base of the big toe) and the calcaneous or heel bone.

2. Draw line "B" to represent the slope of the inner segment of the longitudinal arch at it's junction with the metatarsal border of the arch.

3. Locate "x" and "y". "X" is located at the point where line "A" first touches the imprint. "Y" is located at the point where line "B" first touches the metatarsal border of the arch.

4. Draw line "C" between points "x" and "y". This line is intended to represent the slope of the metatarsal border of the longitudinal arch.

5. Measure the angle at the junction of the lines "A" and "C" with a protractor.

This method of calculating the height of the longitudinal arch (see Figure 1) was judged to be valid by a practising podiatrist in the Victoria area. Further, a reliability correlation coefficient of .96 was reported by Clarke (1933), and .97 by Danford (1935). A full description of the pedograph screening test is included in Appendix A.

Dependent Variables

Leg power. Power is defined as the rate at which work (force x time) is done (Taber, 1962: P. 95; Rasch and Burke, 1963: 162; and Jensen and Schultz, 1967: 367). This was measured by the Standing Broad Jump, where the greater the distance, the greater the power is considered to be exerted by the legs (Johnson and Nelson, 1969: 83). Distances were measured in centimeters. A complete description of the test is included in Appendix B.

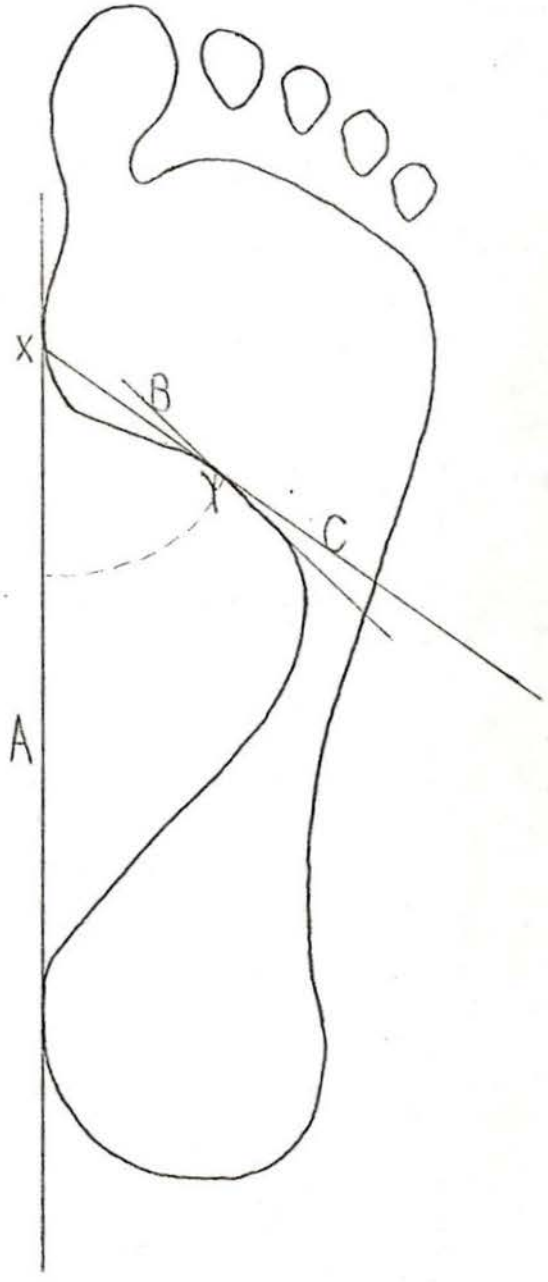

Figure 1. Diagram of the Footprint Angle.

Static balance. Static balance is defined as the ability to maintain static, or stable, equilibrium (Rasch and Burke, 1963: 127; and Guyton, 1971: 666-667). The test employed was a right-footed balancing test upon an inverted gymnasium bench, where it was considered that the greater the time, the greater was the ability to maintain static equilibrium. Time was measured in seconds. Test administration and scoring is included in Appendix B.

Flexibility. Flexibility is defined as the range of motion of an anatomical segment about a joint or series of joints (Cureton, 1941: 382; Holland, 1960: 49; de Vries, 1962: 222; Corbin, 1970: 9; Wessel, 1970: 85; and Sinclair, 1977: 9). The test of flexibility consisted of the ability to flex the toes by bringing them as close to the heel as the range of motion would allow. The difference between the length of the right foot before flexion, and at its maximum point during flexion, was expressed as a percentage of the total length of the right foot. Test administration and scoring is included in Appendix B.

The thoracic curve. This curve in the spinal column commences at the centre of the second dorsal vertebra, and ends at the middle of the twelfth dorsal vertebra. From a lateral view the thoracic curve is convex (Gray,

1974: 52). The purpose of this screening process was to measure the distance along a line from the apex of the thoracic curve to the centre of gravity. The greater the distance, the higher was the crest of the curve. Distances were measured in centimeters. Test administration is included in Appendix B.

The lumbar curve. This curve in the spinal column commences at the center of the last dorsal vertebra, and ends at the sacro-vertebral joint. From a lateral view the lumbar curve is concave (Gray, 1974: 52). The purpose of this test was to measure the distance along a perpendicular from the crest of the lumbar curve to a straight-edge extending from the apex of the thoracic curve to the apex of the pelvic curve. Distances were measured in centimeters. Test administration is included in Appendix B.

Foot alignment. As determined by Morton (1932) and Bleck (1971), the straight foot position is where a line drawn from the center of the heel bisects the cleft between the second and third toes. On each of the pedograph's ink impressions, a perpendicular line was drawn from the center of the back of the heel and extended through the top of the toes to determine how far the foot-print deviated from the straight foot position. Distances were calculated in centimeters. Test administration and scoring is included in Appendix B.

Procedures

A pilot study using ten volunteers was employed to determine reliability of testing procedures on those tests involving subjective evaluation. These were the tests of foot flexibility, the thoracic curve, the lumbar curve and foot alignment. Pearson's product-moment correlation coefficient (Popham and Sirotnik, 1973: 85) was implemented and reliability ratings of .97, .96, .90, and .79 were obtained respectively.

Before testing commenced at each of the schools, the subjects, dressed only in shorts, were shown how each of the tests were to be administered. After this, they completed the six separate tests in the following order:

(1) the pedograph screening test;

(2) the measurement of the thoracic curve;

(3) the measurement of the lumbar curve;

(4) the test of flexibility;

(5) the standing broad jump; and

(6) the test of balance.

Throughout the testing procedure, this investigator was aided by a trained assistant.

Groupings

On the basis of their score on the pedograph test, the 85 subjects were divided into three groups: low arch; normal arch; and high arch. The normal height of the arch was considered to range from 40 degrees to 45 degrees (Clarke, 1933; Schwartz, Britten and Thompson, cited by Clarke, 1933; Danford, 1935; and Rogers, cited by Danford, 1935). Subsequently, due to the clustering of results around the aforementioned normal range, the groups were divided in the following manner:

(1) from three degrees to 35 degrees was considered to be the group with a lower than normal arch (n=22);

(2) from 36 degrees to 51 degrees was considered to be the group with a normal arch (n=41); and

(3) from 52 degrees to 62 degrees was considered to be the group with a higher than normal arch (n=22).

Data Analysis

Firstly, a one way analysis of variance was implemented to determine if significant mean differences occurred between the three groups on each of the dependent variables

(Popham and Sirotnik, 1973: 168-69). Secondly, a multivariate discriminate function analysis was used to determine which variables provided the best predictors for the height of the arch (Cooley and Lohnes, 1971: 243-261).

CHAPTER IV

RESULTS AND DISCUSSION

Results

The results of this study provided little supportive evidence on the affect of the height of the longitudinal arch of the foot upon body segment alignment, and selected motor performance measures of Grade One boys. Table I and Table II show the group means and standard deviations, and the total means and standard deviations on the independent variable, and each of the dependent variables.

Table I

Means and Standard Deviations on the Independent Variables

(* in degrees)

	$\bar{X}$*	S.D.*
Low arch	24.80	8.7
Normal arch	44.14	5.1
High arch	55.18	3.2
Total	41.50	12.56

Table II

Means and Standard Deviations on the Dependent Variables

(* in cm)
(** in %)
(*** in sec)

	Low Arch		Normal Arch		High Arch		Total	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
* Alignment	3.05	1.33	2.59	1.28	2.52	1.16	2.69	1.27
** Flexibility	25.14	5.08	22.94	4.61	26.31	4.26	24.38	14.82
* Thoracic Curve	6.73	1.08	6.55	1.01	6.75	1.33	6.65	1.11
* Lumbar Curve	1.64	0.58	1.81	0.51	1.58	0.71	1.70	0.59
* Standing Broad Jump	117.43	14.64	114.27	19.50	114.45	17.84	115.14	17.78
*** Balance	12.04	15.47	10.57	11.86	16.56	19.98	12.50	15.26

Despite the fact that Grade One boys were studied, the total mean height of arch was found to be similar to that found by Clarke (1933) who tested adult subjects, and Schwartz, Britten, and Thompson (1928).

Table III indicates the range of scores on the independent variable, and each of the dependent variables.

Table III

Range of Scores for Each of the Variables

Height of Arch	59^{o}
Alignment	7.1 cms
Flexibility	21.9%
Thoracic Curve	5.0 cms
Lumbar Curve	2.8 cms
Standing Broad Jump	66.5 cms
Balance	60. secs

Note the large range in the height of arch, which rose from three degrees to 62 degrees. This difference is consistent with that found by Clarke (1933). Scores on the dependent variables were within a normal range.

Table IV shows the correlations between the dependent variables.

Table IV

Correlation Matrix For Dependent Variables

	Align	Flex	Thor	Lumb	Jump	Bal
Align	1.00000					
Flex	-0.17479	1.00000				
Thor	0.04751	0.02764	1.00000			
Lumb	0.12378	-0.02088	0.15141	1.00000		
Jump	0.11405	-0.09980	-0.00586	0.14140	1.00000	
Bal	0.09660	0.06599	0.23501	0.01485	0.02939	1.00000

The results illustrated the very low correlations within the matrix, and the independence of the scores on each of the dependent variables.

Differences Between Variables

A one way analysis of variance was computed for each of the dependent variables between the groups designated as low arch, normal arch, and high arch. The results are included in Table V below.

Table V

One Way Analysis of Variance

(* f Value)

	F Value	Significance
Alignment	1.223	0.2997
Flexibility	4.155	0.0191
Thoracic Curve	0.3079	0.7359
Lumbar Curve	1.258	0.2897
Standing Broad Jump	0.2438	0.7842
Balance	1.118	0.3319

An analysis of Table V demonstrated that flexibility was the only dependent variable to show a significant difference between the group means, and this was significant at the .01 level. When these data were compared by

Scheffe's technique (Weber and Lamb, 1970: 111-112), it was found that this significant difference in flexibility occurred only between groups two (normal arch) and three (high arch).

Predictability of Height of Arch

To determine the predictability of the grouping based on the height of arch, a multivariate discriminate function analysis was computed. Three variables showed a significant relationship to the independent variable beyond the .05 level. These were flexibility, foot alignment, and the depth of the lumbar curve. However, these were not as effective as flexibility alone, which was significant at the .01 level.

Discussion

In this section, comparisons are made between the findings of this study and those conducted by other investigators as summarized in Chapter II.

Increased Range of Motion

It was reported that flexible flat foot was caused either by laxed ligaments, or the widening of the joints between the bones of the foot (Preston, 1974; Paul, 1976;

Vanden Brink, 1976; and Scougal, 1977). Consequently, terms such as "supple", "flexible", "hypermobile", and "hyperlaxed", were all used in describing the effects of the lowering of the longitudinal arch. Kelly (1947) supported the views of these studies and found a low positive significant correlation between ankle pronation and foot flexibility. The results of this study also show a significant difference between the groups on the variable of flexibility, but in contrast to the previous studies, this investigator found that it was the subjects with the higher arch that showed an increase in flexibility, and not the subjects with a lowered arch. It was also noted that the subjects with a lower than normal arch displayed a higher mean score than the subjects with a normal arch.

Leg Power

Boorstein (1925), Lewin (1926), Harris and Beath (1948), and Funk (1967) claimed that a child with flexible flat foot would not want to play running games and would avoid strenuous activity. Also, these authors along with Roehm (1933) and Herzmark (1963) used the term "weak foot" synonymously with the term "flexible flat foot".

Contrary to these opinions, Cureton (1935), and Gruenberg, cited by Cureton, both found insignificant relationships between the height of the longitudinal arch, and the variables of foot strength and leg power. The results of this study concur with Cureton and Gruenberg, as there was no relationship between the height of arch and leg power.

Balance

The results of this study demonstrated that an abnormality in the height of the arch, whether lower than normal, or higher than normal, did not affect the subject's ability to maintain static equilibrium.

Foot Alignment

Omer (1963), Connolly, Regen, and Hillman (1970), Preston (1974), and Sherrill (1976: 115) asserted that an abnormal toeing-out position accompanied the falling of the arch. Helfet (1956) called it the "Charlie Chaplin gait" and Kite (1956) said that when one foot pointed east, the other pointed west.

Contradictory to these opinions, Kelly (1947) found no relationship between ankle pronation and foot alignment. Similarly, the results of this study indicated a non-

significant relationship between the height of the arch and foot alignment.

Body Segment Alignment

Bancroft (1913: 100) stated:

> With flat foot, and the extreme toeing-out positions that accompany or lead to it, the knees and hips are apt to be relaxed, so that the tilt of the pelvis and the curves of the spine above may all be influenced by the posture of the feet.

The results of this study did not support this theory, as the subjects with the lower than normal arch did not differ from the other two groups on the height of the thoracic curve, the depth of the lumbar curve, or foot alignment.

The Mean Height of Arch

As reported earlier, Clarke (1933) discovered that the mean height of arch for his adult subjects was 42 degrees. Similarly, Schwartz, Britten, and Thompson (1928) reported a mean height of arch of 45 degrees. The results of this study display a like pattern, as the mean height of arch was found to be 41.50 degrees.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

Conclusions

Conclusions to this study are presented in the form of answers to the individual problems outlined in the Statement of Problem in Chapter I. In addition, implications for the field are included.

Problem (a). Whether Grade One boys with a lower than normal arch differed from Grade One boys with a normal arch on the variables of leg power, balance, flexibility, the thoracic curve, the lumbar curve and foot alignment.

An analysis of the differences between the two groups on each of the dependent variables, revealed that Grade One boys with a lower than normal arch did not differ significantly from Grade One boys with a normal arch on the selected measures of body alignment, and motor performance.

Problem (b). Whether Grade One boys with a normal arch differed from Grade One boys with a higher than normal arch on the variables of leg power, balance, flexibility, the thoracic curve, the lumbar curve, and foot alignment.

It was discovered that the subjects with the higher than normal arch were significantly more flexible than the subjects with the normal arch at the .05 level. Differences between the two groups on the remaining variables were insignificant.

Problem (c). Whether Grade One boys with a higher than normal arch differed from Grade One boys with a lower than normal arch on the variables of leg power, balance, flexibility, the thoracic curve, the lumbar curve, and foot alignment.

An analysis of the differences between the two groups on each of the dependent variables, revealed that Grade One boys with a lower than normal arch did not differ significantly from Grade One boys with a higher than normal arch on the selected measures of body alignment, and motor performance.

Implications

Although there has been considerable disagreement regarding the influence of the height of the longitudinal arch, very little research has been undertaken to attempt to resolve these conflicts of opinion. This therefore, necessitates the need for further investigation into the disputed problems of flexible flat foot, and the possible affect upon the motor performance of young children.

In the Context of Problem in Chapter I, Shands (1964), Walker (1972), Sherrard (1976), Paul (1976), and Scougal (1977) mentioned six years as an important age for recognizing foot anomalies. They claimed this was due either to the natural development of the muscles and bones of the foot, or to the spontaneous regression of the "fatty pad". While this study supported the fact that there was large variability in the height of the arch at this age, and a mean height of arch that was comparable to the adult population, this investigator questions the advisability of general screening programmes in elementary schools. The results of this study and previous studies have demonstrated that subjects with a lowered arch do not differ from subjects with a normal, or higher than normal arch on the selected measures of motor performance, and body alignment. Therefore, the time and expense of mass screening programmes may not be justified. Physical Education teachers, and parents should not view a lowered arch as a definate problem or disability, but instead should be alert to overt symptoms such as limping, or complaints of foot pain. So, unless these overt symptoms are displayed, children with a fallen arch should participate in normal everyday activities, Physical Education lessons, and sport.

It is recommended that future research examine whether these findings apply to girls. Also, longitudinal studies should examine the initial incidences of flexible flat foot in young females as compared to young males, and the retention of this condition in subsequent years.

In relation to normal everyday activities, it is suggested that studies attempt to determine the affect of the fallen arch upon children in play, as Boorstein (1925), Lewin (1926), Harris and Beath (1948), and Funk (1967) claimed that children with flexible flat foot would not want to play running games, and would avoid strenous activity. In addition, Richardson (1930: 97), Alicandri and Kelly (1963), Funk (1967), and Connolly, Regen, and Hillman (1970) mentioned that the condition could lead to one or more of the following variables: aching calf muscles; night cramps; fatigue and pain. Therefore, it is suggested that investigators examine the affect of a lowered arch upon stamina and endurance in young children.

Finally, objective research should be undertaken to analyze the effectiveness of different methods of remediation.

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APPENDIX A

Independent Variable

ADMINISTRATION OF THE PEDOGRAPH TEST

Instructions

Instructions are announced to the whole group, and then repeated to each subject prior to testing.

Equipment

Scholl's pedograph; imprint sheets; and ink.

Procedures

The subject stands with the left foot against the side of the pedograph. He raises the right foot, and places the back of the heel against the heel plate. He presses down hard on the ink screen, but keeps the left foot on the floor.

APPENDIX B

Dependent Variables

SCORING AND ADMINISTRATION OF THE STANDING BROAD JUMP

Equipment

A gymnasium mat that is eight feet long, four feet wide and two inches thick.

Procedures

The subject stands behind the take-off line, swings the arms backward, bends the knees, then jumps as far as possible with a two-footed take-off. The subject is allowed two attempts, the second attempt following immediately after the first.

The distance is measured in centimeters from the take-off line to the point of contact by the heel that is nearest the take-off line.

SCORING AND ADMINISTRATION OF THE TEST OF STATIC BALANCE

Instructions

Instructions are announced to the whole group, and then repeated to each subject prior to testing.

Equipment

A gymnasium bench, and a stop-watch.

Procedures

For the purposes of this test, the gymnasium bench is inverted. The subject places the right foot along the bottom beam, and rests both hands upon his hips. He then straightens the right leg, and raises the left leg until the bottom of the left foot rests upon the inside border of the right knee. He holds the position for as long as possible. Each subject is allowed two attempts, the second attempt following immediately after the first.

The watch is started the instant the sole of the left foot touches the inside of the right knee, with the hands resting upon the hips. The watch is stopped the instant the hands or left foot lose contact.

SCORING AND ADMINISTRATION OF THE TEST OF FLEXIBILITY

Equipment

A Scholl's imprint sheet.

Procedures

The subject places the right foot on the imprint sheet, so that the back of the heel rests on the centre of the heel guide. The length of the foot is then measured in centimeters from the back of the heel to the top of the "big toe". He then curls the toes beneath the foot to bring them as close to the heel as is possible. When the subject has curled his toes back to the maximum point, a second measurement is taken between the same two points. Each subject is allowed two attempts, the second attempt following immediately after the first.

The difference between the first and second measurement is expressed as a percentage of the first measurement, which is the total length of the foot. For example, if the first, or total length is 20 centimeters and the second measurement is 15 centimeters, the subject is able to move his toes back five centimeters. Five is 25 per cent of 20, therefore he is able to curl his toes 25 per cent of his

total foot length. The best of the two attempts is recorded as a percentage.

ADMINISTRATION OF THE PROCEDURE TO MEASURE THE HEIGHT OF THE THORACIC CURVE

Instructions

Instructions are announced to the whole group, and then repeated to each subject prior to testing.

Equipment

A one centimeter posture grid.

Procedures

The subject stands behind the posture grid, and presents a right lateral view. He is given two instructions:

(1) look straight ahead, and

(2) let your arms hang loosely by your side.

The distance from the apex of the thoracic curve to a line running through the centre of the acromion process, is recorded in centimeters (see Figure 2).

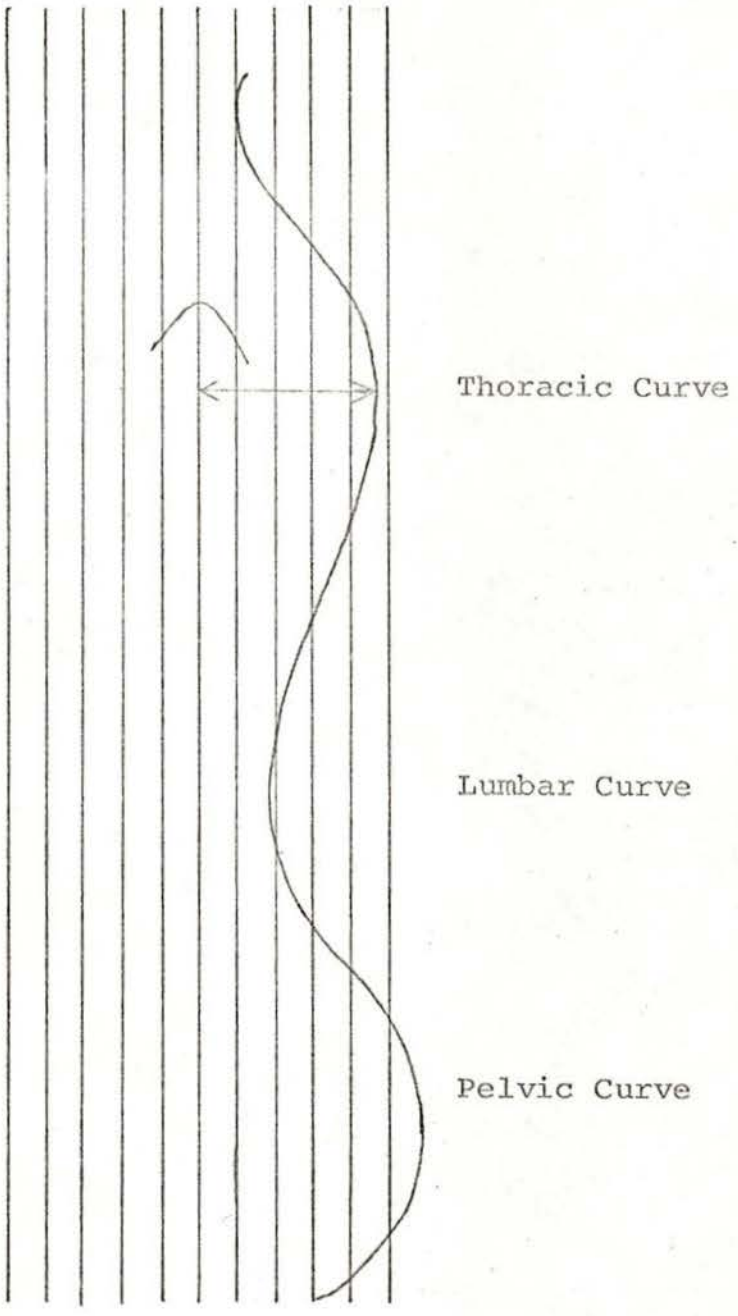

Figure 2. Measurement of the Thoracic Curve.

ADMINISTRATION OF THE PROCEDURE TO MEASURE THE DEPTH OF THE LUMBAR CURVE

Instructions

Instructions to the subject are the same as for the previous test. The instructions are announced to the whole group, and then repeated to each subject prior to testing.

Procedures

The straight-edge is placed on the apex of the thoracic curve, and on the apex of the pelvic curve, and a measurement is taken from the deepest part of the lumbar curve to the inside edge of the straight-edge. However, to ensure that the measurement is the shortest distance between those two points, the ruler leaves the straight-edge at a 90 degree angle by using a right-angled set-square (see Figure 3).

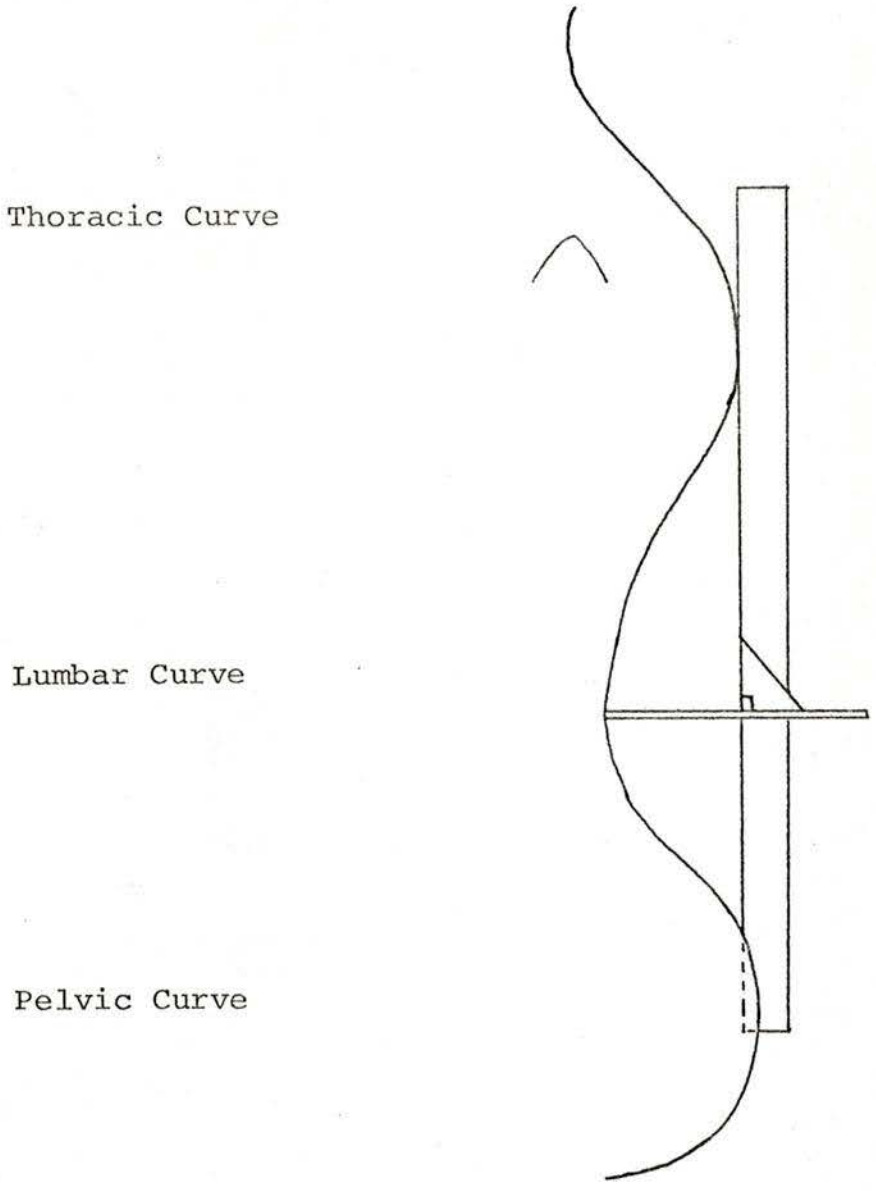

Figure 3. Measurement of the Lumbar Curve.

SCORING AND ADMINISTRATION OF THE PROCEDURE TO DETERMINE THE DEVIATION FROM THE STRAIGHT FOOT POSITION

Equipment

The subject's ink impression on the pedograph sheet.

Procedures

Figure 4 is a diagrammatic representation of the procedure used to calculate the deviation from the straight foot position, described as follows:

1. Locate point "A" which is the base of the first metatarsal bone, and "B" which is the inner border of the calcaneous or heel bone. Join the two points.
2. Locate point "C" which is mid-way between point 1 (where the line "A" "B" first touches the inner border of the heel), and point 2 (where the line "A" "B" last touches the inner border of the heel).
3. Draw line "C" "D" parallel to the line "F" "G" which runs through the back of the heel guide. "D" is the point at which the line parallel to "F" "G" cuts the outer border of the calcanceous or heel bone.

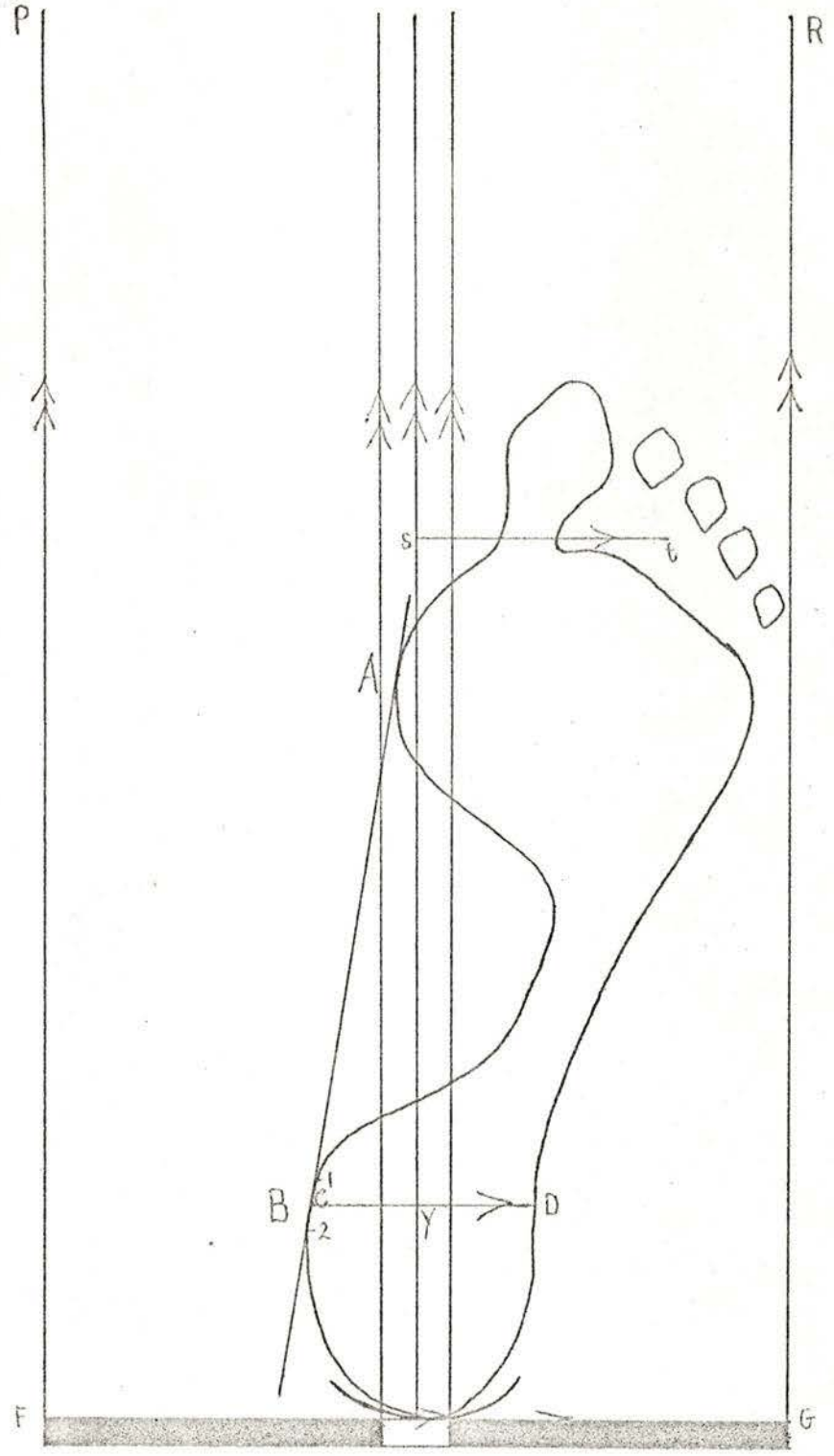

Figure 4. Calculation of the Deviation from the Straight-Foot Position Using a Scholl's Ink Impression Sheet.

4. Locate point "Y" which is the centre of "C" "D", and draw line "Y" parallel to "P" "F" and "R" "G" which are located on the imprint sheets.
5. Locate "t" which is a point in the cleft between the second and third toes, and draw a line parallel to "C" "D" to cut line "Y" at "S".
6. Line "S" "t" is the distance the foot deviates from the straight-foot position.

To avoid negative scores, the greatest toeing-in distance is deemed zero. For example, if the greatest toeing-in distance is minus two centimeters, it is taken as zero, and two centimeters are subsequently added to the other subjects' scores.

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Title of Thesis/Dissertation

THE RELATIONSHIP OF THE HEIGHT OF THE LONGITUDINAL ARCH OF THE FOOT TO THE ALIGNMENT OF BODY SEGMENTS AND SELECTED MOTOR PERFORMANCE MEASURES

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