The role of the Trendelenburg Test in the examination of gait

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Background: The Trendelenburg Test was developed by Friedrich Trendelenburg, an orthopaedic surgeon, in 1895. Contemporary evidence shows the Trendelenburg Test is now being used internationally by a wide variety of practitioners.
Method: This review describes the evolution of the Trendelenburg Test and its role within the examination of gait and examines the evidence relating clinical assessment using the Trendelenburg Test to the mechanics of walking. Literature was reviewed from electronic databases CINAHL, Medline, ScienceDirect, Ovid. Papers written in English were reviewed.
Results: The possible outcomes of the Trendelenburg Test and its interpretation are defined. The outcomes and interpretation for the future use of the Trendelenburg Test are discussed.
Conclusion: Further research is required into the biomechanics of the Trendelenburg Test and its relationship to functional anatomy and to investigate its reliability and validity within specific populations.

Keywords: Trendelenburg Test, orthopaedic clinical test, gait

Introduction

The Trendelenburg Test was developed by Friedrich Trendelenburg, an orthopaedic surgeon, in Bonn, Germany in 1895.[1–5] It was a progression of previous work by Dupytren on '- glissement vertical'.[1] The Trendelenburg Test was created to assist doctors in examining the gait of patients with congenital dislocation of the hip (CDH) and progressive muscular atrophy.[1,5] The test is conducted in the position of single leg stance.[6] This position is seen in many daily functions such as walking and running, or in sports such as football, rugby, hockey, gymnastics and skiing. An individual walks over 10 000 steps per day on average[7–9] and a professional football player runs over 10 km per game.[10,11] Therefore, single leg stance is a position both normal and sporting individuals go into repetitively and frequently.

During single leg stance, the weight bearing limb forms a closed kinetic chain with the floor and the non weight bearing limb forms an open kinetic chain.[12] If the two limbs and pelvis are considered as a whole then at the point of single leg stance, they are in 'controlled open kinetic chain'[13] (Figure 1).

Loss of control at any point in this chain may cause uncontrolled movement at that particular link in the chain, or at a link proximal or distal to it,[6,13] where uncontrolled movement may be termed dysfunction and dysfunction may cause symptoms or disability.[14] Symptoms or disability may therefore manifest at the site of dysfunction, or a joint proximal or distal to it (Figure 2). Therefore, by examining single limb stance, the Trendelenburg Test is a functional test for this kinetic chain of joints and their ability to transduce force across them.

The Trendelenburg Test

Originally, Trendelenburg described his test as "standing on the treated (affected) leg and raising the buttock of the other side up to or above the horizontal line" [1,5] (Figure 3). He stated that the test was positive if the patient was unable to stand on the treated (affected) leg and raise the buttock of the other side up to or above the horizontal line[1,5] (Figure 4). Trendelenburg felt that this indicated "… that the abductors of the standing leg cannot keep the pelvis horizontal".[1,5]

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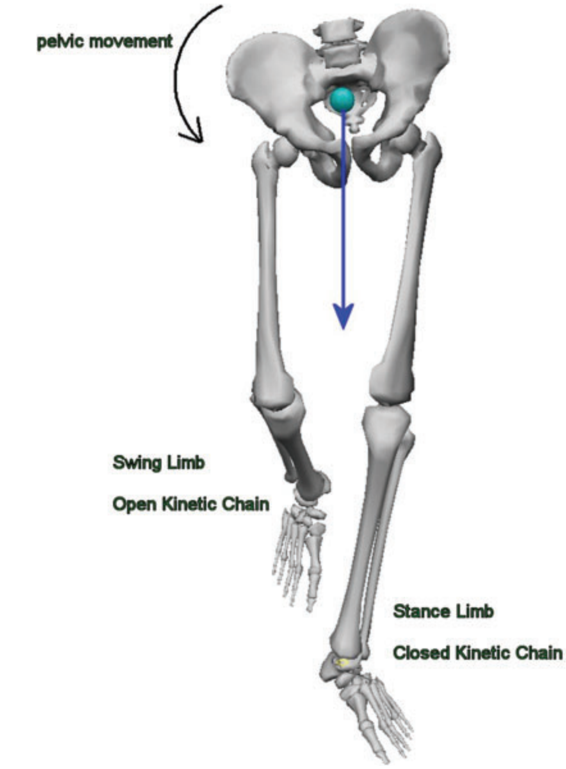

Figure 1 **The kinetic chain at mid-stance**

Trendelenburg stated that this inability to support the pelvis against gravity during the test was due to the fact that, "as a result of the anatomical changes resulting from dislocation, they (the hip abductors)

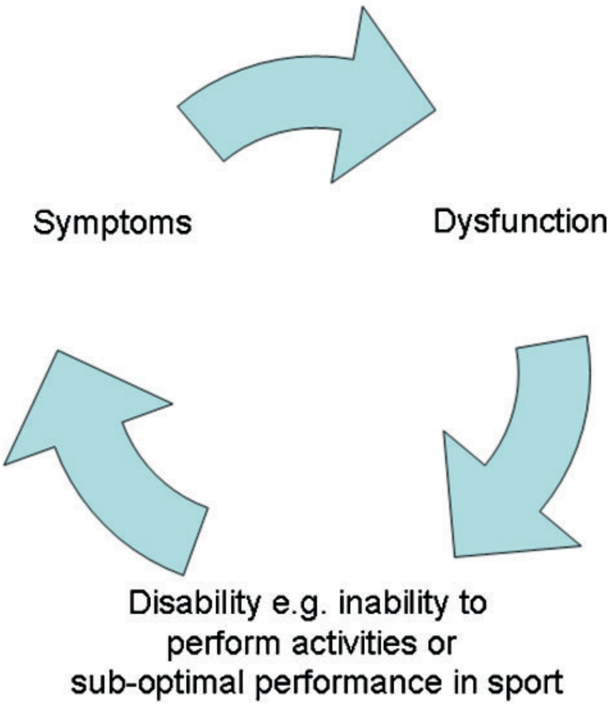

Figure 2 **The relationship between symptoms, dysfunction and disability**

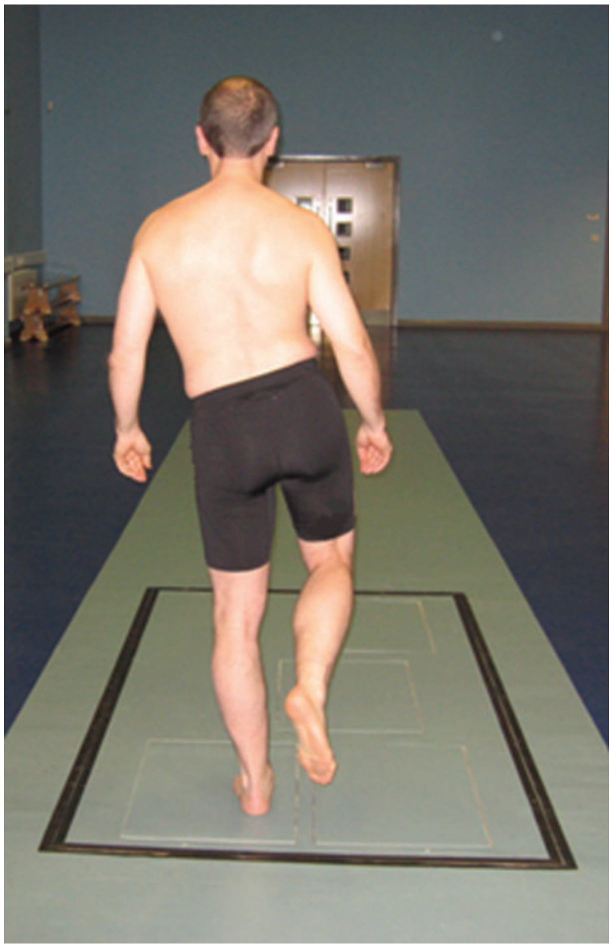

Figure 3 **The response is NORMAL (i.e. the test is 'negative') if the pelvis on the non-stance can be elevated as high as hip abduction on the stance side will allow**

are incapable of holding it. The gluteus medius is reduced to about one third of the size, and the direction of its fibres is so altered that it cannot act at all as an abductor. Its anterior part is directed obliquely from the back at the top to the front below, the middle part is horizontal and the posterior part which alone runs in something like the right direction, is so extremely shortened that its power of traction must be nil. It goes without saying that the gluteus minimus is also completely destroyed, so the whole muscular apparatus providing for abduction of the hip fails…".[1,5] Conversely, Trendelenburg stated that "…The fact that the pelvis remains horizontal and does not drop on the side of the swinging leg is due to the action of the abductors of the hip joint, the gluteus medius, the gluteus partly to the gluteus maximus …".[1,5] Therefore, a negative test indicates competent hip abductor muscles.

Trendelenburg described the effect that this hip abductor weakness had upon the patient's gait. "The

Figure 4 **The response is ABNORMAL (i.e. the test is 'positive') if the pelvis on the non-stance cannot be elevated**

opposing swings (seen in the Trendelenburg gait) meet between the sacrum and lumbar spine: this is the pivot of the movements. It looks as if almost a hinge were inserted here, about which the spine moves in relation to the sacrum, and these hinging movements are prompt and full in a way hardly possible in a normal body. The joint has become adapted to the increased demands, and we must expect to find corresponding anatomical changes in older patients''.[1] He describes autopsy findings of the lumbar spine from these patients where ''a very unusual mobility in the lumbo-sacral joint'' was present and ''the intervertebral substance between the last lumbar vertebra and the sacrum was much thicker than normal''.[1]

Trendelenburg wrote his original article in the first person using a narrative style and based it on his own subjective observations. This was typical of fellow authors of the period such as Paget (Osteitis Deformans – 1877),[15] Baker (Cyst – 1885),[16] Still (Still's disease – 1897)[17] and Goldthwait (Sciatica – 1911).[16,18] Presumably in an attempt to validate his findings, he used the latest scientific equipment available in 1895 – photography. Later that very year, Wilhelm Rontgen demonstrated 'X-Rays' for the first time.[16]

The Trendelenburg Test is often cited as being a useful clinical test. Standard 6 in the Chartered Society of Physiotherapy Core Standards document makes an explicit requirement for members to use published, standardised outcomes (tests) in clinical practice.[19,20] McDowell states that ''An outcome measure should be standardised, with explicit instructions for administration''.[21] However Youdas *et al.* stated that Trendelenburg's original description of the test lacked an ''operational definition'',[22] i.e. a clear method and interpretation. This lack of a clear method for administering and interpreting the test may explain Hardcastle and Nades's observation: ''(they) found little agreement amongst colleagues about performance or interpretation of the (Trendelenburg) Test''.[23]

Billis *et al.*[24] and Hestboek and Leboeuf-Yde[25] found both physiotherapists and chiropractors had different methods for performing similar clinical lumbo-pelvic tests. French *et al.*[26] found that chiropractors interpreted the response to common, clinical lumbo-pelvic tests differently. These studies showed poor intra- and inter-tester reliability.[24–26] It may be concluded that where clinical tests have different methods or interpretation, then intra- and inter-tester reliability is inevitably poor. Equally, to raise intra- and inter-tester reliability, clinical tests need to be 'precise, reproducible and highly standardized'.[27] Interestingly, no studies were found of orthopaedic surgeons' reliability when performing common clinical tests for the lumbo-pelvic region.

Due to this confusion over methods and interpretation, Hardcastle and Nade[23] investigated the Trendelenburg Test. In 1985, Hardcastle and Nade became the first authors since Trendelenburg himself, nearly 100 years before in 1895, to attempt to define the method for performing the Trendelenburg Test and how to interpret its response.

Hardcastle and Nade defined the method as follows:

a. The examiner stands behind the patient and observes the angle between the pelvis (the line joining the iliac crests) and the ground
b. The patient is asked to raise from the ground the foot of the side not being tested, holding the hip joint at between neutral and 30 degrees of flexion. The knee should be flexed enough to allow the foot to be clear of the ground to nullify the effects of the rectus femoris muscle. The position of the pelvis is again noted. A supporting stick can be used in the hand only of the side of the weight

bearing hip; alternatively, both shoulders can be supported by the examiner so as to maintain balance without a stick

c. Once balanced, the patient is *then* asked to raise the non-stance of the pelvis as high as possible. The examiner may support the patient by holding the arm on the *stance* side
d. If the patient leans too far over to the side of the weight-bearing hip, the examiner corrects this by gentle pressure on the shoulders to bring the vertebra prominens approximately over the centre of the hip joint and the weight-bearing foot.

Hardcastle and Nade interpreted the test as follows:
Response

a. The response is NORMAL (i.e. the test is 'negative') if the pelvis on the non-stance can be elevated as high as hip abduction on the stance side will allow, and providing this posture can be maintained for 30 s with the vertebra prominens centred over the hip and foot (Figure 3)
b. The response is ABNORMAL (i.e. the test is 'positive') if this cannot be done. This includes responses where the pelvis is elevated on the non-stance side above the stance side, but where this elevation is not maximal (Figure 4)
c. The response is ABNORMAL if the pelvis can be lifted on command (Figure 3), but cannot be maintained in that position for 30 s (Figure 4).

The time taken before the pelvis starts to fall is recorded. By introducing a time element, the Trendelenburg Test can be objectively recorded for comparison purposes.

Hardcastle and Nade were the first to define exclusion criteria for the test. They stated that the test could not be used on all patients. Hardcastle and Nade found that, in children under four, the Trendelenburg Test could not be reliably used, and over four years of age only if they could understand and fully co-operate.[23]

Hardcastle and Nade also defined false negative and positive responses to the Trendelenburg Test: *False* negatives are particularly evident in neurological disorders and patients with pain in the hip.[23] *False* positives also occur in patients with severe scoliosis, pain, poor balance, lack of co-operation or understanding[23] (Table 1).

The use of the Trendelenburg Test to assess different conditions

Hardcastle and Nade used the latest scientific equipment available: videotape, slides and electromyography. In contrast to Trendelenburg, they used a laboratory based study using an experimental, same-subject crossover design. Inter- and intra-comparative group analyses were made. Trendelenburg used only subjects with CDH and progressive muscular atrophy but Hardcastle and Nade used a broader population with subgroups of subjects including: total hip arthroplasty, Legg-Calve-Perthes disease, incomplete paraplegia, muscular dystrophy, nerve root entrapment, cerebral palsy, poliomyelitis, hemiplegia, scoliosis, ankylosing spondylitis, iliac crest disease, CDH, subluxation, coxa vara, slipped capital femoral epiphysis, fractured neck of femur, osteoarthritis, avascular necrosis and asymptomatic subjects. Trendelenburg stated two possibilities for a positive test, i.e. being unable to raise the pelvis up to or above the horizontal. He did not clearly define how to interpret the test. Hardcastle and Nade clarified how to interpret the test giving three well defined possibilities. They also included timing of the test hence creating a more objective test.

Contemporary evidence shows that the Trendelenburg Test is now being used internationally[22,28–40] by a wide variety of orthopaedic practitioners.[2,23,28–31,34,37,39–43] These practitioners now use the Trendelenburg Test to examine the gaits of patients with a much wider variety of conditions than just CDH and progressive muscular atrophy. Most subsequent orthopaedic and therapeutic literature has used the Trendelenburg Test when studying structures in and around the hip:

- Pai (1996) (total hip replacement (THR))[39]
- Ramesh *et al.* (1996) (THR – superior gluteal nerve damage)[41]
- Vasudevan *et al.* (1997) (hip assessment)[2]
- Downing *et al.* (2001) (THR)[38]
- Asayama *et al.* (2002) (THR)[28]

Table 1 False responses to the Trendelenburg Test

Causes of false negatives	Causes of false positives
Use of supra-pelvic muscles	Pain
Use of psoas and rectus femoris	Poor balance
Wide lateral translocation of the trunk to allow balance over the hip as a fulcrum	Lack of co-operation or understanding
	Costo-pelvic impingement

- Van Iersel and Mulley (2004) (literature review – Waddling gait)[44]
- DiMattia *et al*. (2005) (single leg dip)[32]
- Inan *et al*. (2005) (pelvic support osteotomy)[42]
- Rozbruch *et al*. (2005) (Ilazirov hip – paediatrics)[34]
- Westhoff *et al*. (2005) (Legg-Calves-Perthes)[29]
- Youdas *et al*. (2006) (abductor muscle fatigue).[22]

The literature describes different methods for performing the test[23,38] (Table 2).

The Trendelenburg gait has even been used to describe the gait of animals including apes[45] and ducks.[44] Within these studies, the test is usually described vaguely,[23,44] however, where the method of performing the Trendelenburg Test is stated clearly,

Table 2 Different authors' definitions of possible outcomes of the Trendelenburg Test

Author and source of description of test	Positive test definition
Asayama *et al.*[28] Taken and referenced from Hardcastle and Nade[23]	The pelvis on the non-stance side moves more downward below the level of the stance side in proportion to the degree of the abductor weakness < or = −20. This also accepts delayed positive response if unable to hold for 30 s
DiMattia *et al.*[32] Taken from Hardcastle and Nade[23]	The test is considered positive when the pelvis on the non-weight bearing side lowers, although no quantification was suggested. This does not accept a delayed positive response
Downing *et al.*[38] Taken from Hardcastle and Nade[23]	No description in text, although it accepts delayed positive response if unable to hold for 30 s
Hardcastle and Nade[23]	Accepts delayed positive response if unable to hold for 30 s and cites Mitchell (1973)
Inan *et al.*[42] Taken from Hardcastle and Nade[23]	If the iliac crest was high on the affected side and low on the affected side. No strict interpretation of positive result or delayed. Yes if initially negative but, after standing on the leg for a short time, the pelvis gradually began to fall toward the unsupported side
Pai.[39] Taken from Hardcastle and Nade[23]	Normal. If the pelvis on the non stance side can be elevated high up and is maintained for 30 s. Elevation of the pelvis is present but not maximal. Pelvis is elevated but not maintained for 30 s. No elevation of the non stance side. Drooping of the pelvis. Non-valid response: presence of hip pain, uncooperative patient. (1–2 were normal, 3–5 were abnormal) Did not formally state acceptance of delayed positive response but includes it into his own 6 grade scale of responses
Shampo[4]	Falling rather than elevation of the gluteal fold on the unaffected side when the patient stands on the affected leg and raises the other
Ramesh *et al.*[41] Taken from Hardcastle and Nade[23]	Normal. The pelvis on the non-weight bearing side can be elevated high and maintained for 30 s. Abnormal. Elevation of the pelvis is present but not to the maximum. Abnormal. The pelvis is elevated but cannot be maintained for 30 s. Abnormal. There is a dropping of their pelvis on the non-weight-bearing side. (Only acknowledges 4 as an abnormal response)
Rozbruch *et al.*[34]	Photograph in text but no description. Undescribed Trendelenburg Test
Van Iersel and Mulley.[44] Reference Trendelenburg	The trunk bends to the side of stance. There is falling and rising of the pelvis on the horizontal axis. The pelvis falls to the swinging side (i.e. the side in which the leg is off the ground).
Vasudevan *et al.*[2] References Apleys	The pelvis drops on the unsupported side – 3 possible mechanisms: Supra-pelvic, Costo-pelvic impingement as in scoliosis, Pelvic. This is due to loss of the fulcrum as in developmental dysplasia of the hip, or of the lever mechanism as in non-union of the femoral neck, or of power as in poliomyelitis or muscular dystrophy. Infra-pelvic. This is caused by medial deviation of the mechanical axis of the lower limb
Westhoff *et al.*[29] References Trendelenburg	Pelvic drop to the swinging limb during single stance phase of more than 4 degrees and/or maximum pelvic drop in the stance phase of more than 8 degrees. Trunk lean in relation to the pelvis to the stance limb during single stance phase of more than 5 degrees. Hip adduction in single stance phase of more than 9 degrees and/or maximum hip adduction in the stance phase of more than 11 degrees
Youdas *et al.*[22] References Hardcastle and Nade[23]	Uses Hardcastle and Nade however flexes the hip to 45 degrees on the non weight bearing (NWB) side hence is not accurate – it should be 30 degrees. This also accepts delayed positive response if unable to hold for 30 s

the authors have used the method proposed by Hardcastle and Nade (1985).[22,28,32,38,39,42,44] The only authors not to use this method were Van Iersel and Mulley,[44] Vasudevan *et al.*,[2] and Westhoff *et al.*[29]

Most current literature does not define, within the study's method, how to interpret the test. However, this recent literature appears in agreement that, when the test is positive, the pelvis drops on the non-weight bearing side.[2,4,22,23,28,29,32,34,38,39,41,42,44] None of this literature defines how far the non-weight bearing pelvis can drop before it is judged as a positive test. It is a subjective decision and this does not help interpretation of the test. Westhoff *et al.* summarised this succinctly: 'The Trendelenburg (and Duchene) gaits are well described in the literature. However, there are no objective criteria defining abnormal gait changes'.[29]

Subsequently, only two authors have objectively defined when this pelvic drop becomes positive. Asayama *et al.* stated that a 'tilt angle' of greater than 2 degrees indicated a positive Trendelenburg Test.[28] Westhoff *et al.* stated that 'Pelvic drop to the swinging limb during single stance phase of more than 4 degrees and/or maximum pelvic drop in the stance phase of more than 8 degrees'[29] indicated a positive test. These refinements have made the Trendelenburg test more objective, however, many practitioners do not have access to the 3SPACE magnetic sensor system used by Asayama *et al.* or the VICON 512 gait system used by Westhoff *et al.* Youdas *et al.* used a commonly available clinical measurement device, the universal goniometer. However, Youdas *et al.* concluded that the minimal detectable change in pelvis on femur angle using the device was 4 degrees.[46] Commonly, practitioners visually 'eyeball' the Trendelenburg Test. They may find it difficult clinically to identify 2 degrees of tilt in a pelvis.

These studies have established that movement of the pelvis on the femur can be measured accurately, however, the equipment required is not commonly available to practitioners. The equipment that is commonly available is not sensitive enough to detect these small changes in pelvic movement. All of these studies confined themselves, as did Trendelenburg, to coronal plane motion. There is no existing data for combined sagittal, coronal and transverse plane pelvic motion during the Trendelenburg Test.

Despite this explosion in different populations that the test is now being used upon, and improved definition for interpreting the test, evidence states that it cannot be used on all patients. Rozbruch *et al.* agree with Hardcastle and Nade regarding paediatric patients. They found that, despite the Trendelenburg gait being one of the 'hallmarks' of his paediatric subjects, 'Younger children often do not manifest a pelvic drop during gait due to their lighter weight and shorter stride length. As they become adolescents and their height, lower-extremity length, and weight increase, the pelvic drop becomes more apparent'.[34] Hence, the Trendelenburg Test appears inappropriate for individuals who cannot understand what is required to perform the test or those who have not reached adolescence.

Recently, Roussell *et al.* have used the Trendelenburg Test to study problems proximal to the hip. Roussell *et al.*[34] were the first to study the relationship between non-specific low back pain and the Trendelenburg Test (n=36). This author notes that Roussell *et al.* adhered strictly to Hardcastle's method and interpretation of the Trendelenburg Test. This is in contrast to previous studies. This may be one explanation for the conclusion of Roussell *et al.* that the Trendelenburg Test had good test-retest reliability for the non-specific low back pain population.[47] Their study however did not find any correlation between the Trendelenburg Test, low back pain and disability.

Conclusion

The Trendelenburg Test has existed for over a century. It was initially intended for use in two specific populations. Since then, it has suffered from a poor description of both its method and interpretation. Over the twentieth century, new therapeutic professions were born. These different practitioners have implemented the original test on a more generalised population. This combination of different populations, inconsistent method of application and inconsistent interpretation of the test may have contributed to the poor inter- and intra-tester reliability found within the literature.

The landmark work of Hardcastle and Nade[23] has now become the standard for the test's method and interpretation. By combining this study with those of Asayama *et al.*[28] and Westhoff *et al.*,[29] the original test is refined into a modern, objective clinical test. However, a limitation of this combined evidence is that the data are confined to the coronal plane. Despite human motion occurring in three planes of motion, there are no data for combined sagittal, coronal and transverse plane pelvic motion during the Trendelenburg Test.

The concept of the kinetic chain has recently caused authors to question if the test is valid for symptoms remote from the hip. Roussell *et al.*[47] were the first to use the test on symptoms in the proximal part of the kinetic chain – non-specific low back pain patients. Their adherence to a strict method and interpretation is in contrast to previous authors. This strict adherence may explain why they had good intra-tester reliability for the test.

It is clear that further research is required into the biomechanics of the Trendelenburg Test and its relationship to functional anatomy. To conduct this research, optimally the method and interpretation of Hardcastle and Nade[23] should be used, along with the objective interpretation of the test as proposed by Asayama *et al.*[28] and Westhoff *et al.*[29] Applying strict adherence to these methods, as Roussell *et al.*[47] did, should raise intra- and inter-tester reliability. The collection of data for sagittal, coronal and transverse plane pelvic motion during the test would fill an evidence vacuum. Future research should investigate the reliability and validity of the Trendelenburg Test within specific populations. This may in turn help explain the mechanisms and presentations of specific gait types.

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