



Is there an association between the use of heeled footwear and schizophrenia?

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Summary Existing etiological and pathogenetical theories of schizophrenia have only been able to find support in some epidemiological, clinical, and pathophysiological facts. A selective literature review and synthesis is used to present a hypothesis that finds support in all facts and is contradicted by none.

Heeled footwear began to be used more than a 1000 years ago, and led to the occurrence of the first cases of schizophrenia. Industrialization of shoe production increased schizophrenia prevalence. Mechanization of the production started in Massachusetts, spread from there to England and Germany, and then to the rest of Western Europe. A remarkable increase in schizophrenia prevalence followed the same pattern. In Baden in Germany the increasing stream of young patients more or less hastily progrediating to a severe state of cognitive impairment made it possible for Kraepelin to delineate dementia praecox as a nosological entity. The patients continued to use heeled shoes after they were admitted to the hospitals and the disease progrediated.

High rates of schizophrenia are found among first-generation immigrants from regions with a warmer climate to regions with a colder climate, where the use of shoes is more common. Still higher rates among second-generation immigrants are caused by the use of shoes during the onset of walking at an age of about 11–12 months. Other findings point to the importance of this in the later development of schizophrenia. A child born in January–March begins to walk in December–March, when it's cold outside and the chances of going barefoot are smaller. They are also smaller in urban settings.

During walking synchronised stimuli from mechanoreceptors in the lower extremities increase activity in cerebello-thalamo-cortico-cerebellar loops through their action on NMDA-receptors. Using heeled shoes leads to weaker stimulation of the loops. Reduced cortical activity changes dopaminergic function which involves the basal ganglia-thalamo-cortical-nigro-basal ganglia loops. Bicycle riding reduces depression in schizophrenia due to stronger stimulation by improved lengthening contractions of the triceps surae muscles. Electrode stimulation of cerebellar loops normally stimulated by mechanoreceptors in the lower extremities could improve functioning in schizophrenia.

Cross-sectional prevalence studies of the association between the use of heeled footwear and schizophrenia should be made in immigrants from regions with a warmer climate or in groups of people who began to wear shoes at different ages.

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Introduction

Schizophrenia is the most serious mental illness characterized by disturbances of thought, behaviour and mood appearing in young adults and by a deteriorating course. Many etiological hypotheses have been advanced, e.g., that schizophrenia is wholly genetic, or that environmental factors such as pregnancy or birth complications or early infections are also important, but have not succeeded in finding a correspondence between etiology, clinical findings, course and outcome, brain pathology and probable variations of prevalence. It is considered to be either a developmental or a degenerative disease, or a combination of both [1]. The diversity of symptoms have been difficult to explain by a unifying disease process [2].

History and epidemiology

The evolution of bipedal, plantigrade gait probably occurred about ten million years ago. The first type of shoe was a simple wraparound of leather, with the basic construction of a moccasin. Although sandals were the most common footwear in most early civilizations, shoes were also worn. The oldest depiction of a heeled shoe comes from Mesopotamia [3], and in this part of the world we also find the first institutions making provisions for mental disorders. Possibly they and all the others that followed were created because of the imperative need to care for people affected by schizophrenia. Hospitals with psychiatric divisions were created in Baghdad (AD 750) and in Cairo (873). Special insane asylums were built in Damascus (800), Aleppo (1270), and in the Muslim-ruled Spanish city of Grenada (1365) [4].

In Europe around 1400 we find Middle Eastern shoes with a wedged sole, and cloglike overshoes called pattens, which by then were wedge-shaped at the back, raising the foot at the heel slightly above the fore-part of the foot, and thus functioning as heeled shoes. The creation of institutions for the insane was also imported to Europe from the Orient as hospitals with psychiatric divisions were erected in Paris, Lyon, Munich, Basel, and Zurich in the 13th century. Bethlehem hospital in London began receiving the insane in 1377. The first Christian European asylums were founded in Valencia (1409), Saragosa (1425), Seville and Valladolid (1436), and Toledo (1483) under the influence of Islam [4]. During the 15th and 16th centuries the number of asylums in Europe grew dramatically.

In the beginning schizophrenia appears to be more common in the upper classes. Possible early victims were King Richard II (1367–1400) and Henry VI (1421–1471) of England, his grandfather Charles VI (1368–1422) of France, his mother Jeanne de Bourbon, and his uncle Louis II de Bourbon, Erik XIV (1535–1577) of Sweden, Juana (1479–1555) of Castile, her grandmother Isabella of Portugal and her grandson Don Carlos (1545–1563), of Schiller and Verdi fame [5]. Probably the upper classes began using heeled footwear earlier than the lower classes. Several studies from India since the 1930s confirm that schizophrenia first affects the upper classes [6]. The relation to a change in the use of footwear is also apparent here, since modern European and American footwear probably were being more common in India during these years. As early as 1740 the Danish–French anatomist Jakob Winslow [7] warned against the wearing of heeled shoes, expecting it to be the cause of certain infirmities which appear not to have any relation to it.

In England the heeled shoe became fashionable from the beginning of the 17th century. The Civil Wars (1642–1651) brought army orders for boots and shoes, and the emergence of the modern pattern of shoemaking [8]. An increase in the use of heeled footwear followed and probably a gradual increase in the prevalence of schizophrenia [9]. Torrey and Miller [10] suggest that insanity rates increased at least sevenfold between the mid-18th and the mid-20th centuries. From the beginning of the 19th century a probable increase in the use of heeled footwear by children learning to walk led to the appearance of the classical juvenile type of schizophrenia [11] (see Fig. 1).

In the United States insanity rates appear to have increased even greater than in England between the mid-18th and the mid-20th centuries. Shoe production increased in Massachusetts after the Revolution (1776–1783), and the prevalence of insanity/schizophrenia increased from the 1830s. It was common opinion during this time that mental diseases increased, and that the increase was most pronounced in the United States. During the 1830s and 1840s asylums were built in almost every state. Torrey and Bowler [18] report that in 1852 insanity was more common in manufacturing and mercantile communities in Massachusetts than in farming areas. These communities probably took part in the early industrial production or distribution of footwear in this state, making it probable that they used factory-made footwear earlier than other communities. The Civil War (1861–1865) gave a major impetus to mechanised shoe production, and the establishment of a shoe machine industry in

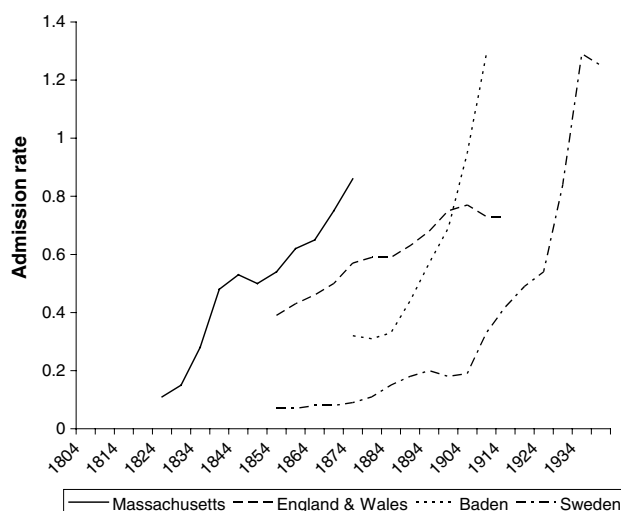


Figure 1 Total admissions (all diagnoses) per 1000 population to asylums in Massachusetts (averages of two yearly admissions per decennium) [12], England and Wales (five-year averages) [13], Baden (five- and four-year averages) [14], and Sweden (five-year averages) [15–17], during the 19th and beginning of the 20th century.

Massachusetts led to shoes being made quickly and inexpensively, the use of factory-made, heeled footwear spread to the masses in the United States, and then to England, Germany, the rest of Western Europe, and all over the world, and the prevalence of schizophrenia increased everywhere. White [19] reviewed the data of the 1880 Census and noticed that the prevalence of insanity was higher in the northeastern states, and that it declined with the distance from them. A graph of admissions to asylums in Massachusetts shows a steep rise between 1828 and 1843. The increase of admissions to asylums in Connecticut comes some 20 years later, in New York State some 30 years later, and in Pennsylvania there is but a slow rise up to 1875.

In Germany mechanised shoe production was established later than in the United States and England. Total admissions to asylums in Baden rose steeply between 1887 and 1907. Kraepelin was director of the Psychiatric Clinic at the University of Heidelberg 1891–1903, and in the middle of the steeply rising phase of the schizophrenia epidemic in this state he wrote the 4–7th editions of his textbook. An increasing stream of young patients more or less hastily progressing to a state of severe cognitive impairment made it possible for Kraepelin [20] to delineate dementia praecox as a nosological entity.

In Sweden industrial shoe production started in the 1870s, but did not make a breakthrough until tariff protection increased in 1897. Around 1908–1910 factory made shoes were available for the rural population. In 1913 the shoe industry had enough capacity for the needs of the Swedish

market. During World War I there was a shortage, thereafter the prevalence of schizophrenia rose.

Hare [21] discusses the increase of admissions to asylums in England between 1859 and 1909 and concludes that schizophrenia could account for at least 40% of the increase. Eaton et al. [22] state that the majority of patients with psychosis in Massachusetts from 1840 to 1940 had schizophrenia. The situation in Sweden in the beginning of the 20th century probably was similar, manic-depressive disorder did not show much change over time, and the number of beds was always insufficient to allow admission of minor afflictions. Shorter [11] suggests that neurosyphilis and alcoholism together represented overall only a fraction of all admissions in the Western World, and that there is enough evidence to justify the conjecture that the incidence of schizophrenia rose significantly during the 19th century. It is probably justifiable to assume that the figure illustrates the approximate rise in incidence of schizophrenia in the four populations.

After heeled shoes is introduced into a population the first cases of schizophrenia appear and then the increase in prevalence of schizophrenia follows the increase in use of heeled shoes with some delay. After the prevalence of schizophrenia has reached a maximum there probably is some decrease, although there is no decrease in the use of heeled shoes. Evidence from nearly a century of epidemiological research indicates that schizophrenia occurs in all populations with a prevalence rate in the range of 1.4–4.6 per 1000 population [23]. Different methods of case finding and ascertainment will result in different prevalence rates

and so will demographic differences. Many studies of geographical variations have been criticized for imperfect methodologies but can probably not be ignored, especially not the modern migration studies. They do, however, not point in any single etiological direction.

In the mid-latitude climates people traditionally wore flat shoes or boots, in some regions and during summer some people, particularly children, went barefoot, in Sweden for example well into the 20th century. Böök [24], in a study of an isolated population of predominantly Finnish ethnicity in the Torne Valley in Sweden in 1949, found a schizophrenia prevalence rate of 9.5 per 1000, and Böök et al. [25], in a re-study in 1977, 17 per 1000, one of the highest rates found in any major study in the world to date. In Ireland insanity rates appears to have increased more than in England between the mid-18th and the mid-20th centuries [10]. High rates of schizophrenia have consistently been reported and might partly be explained by selective out-migration over several generations [26]. Most of the Irish have, however, gone barefoot well into the 19th century. Rainfall is important for the use of footwear, the western parts of Ireland have more rainfall and also have a higher rate of schizophrenia than the north-eastern parts. Torrey et al. [27] found a prevalence rate in a rural area in Western Ireland more than seven times the rate found in Dublin [28], where there also is less rainfall. Data collected 1962–1966 show that the prevalence of schizophrenia in Istria was twice that in the rest of Croatia, which probably indicates that the change to heeled shoes occurred earlier in Istria, which belonged to Italy 1919–1947, had a large proportion of Italian inhabitants and probably was more influenced by West European fashions [29]. Opankes, a one-piece moccasin-style construction, were widely worn in rural Balkan regions, where they were often made by the wearers themselves, and mass produced by the 19th century. The consistently high rates also found in Istria might also be partly explained by selective out-migration over several generations [26]. Among Native Americans, who used moccasins, a relative infrequency of schizophrenia has been noted [6]. The Hutterites and the Amish are members of conservative Christian groups of Austrian, Swiss, and German origin now living in the United States and Canada where they operate farms, remain aloof from outside society and retain their uniform 16th and 17th century European folk costumes, which included flat shoes. In the 1930s insanity was said to be almost non-existent in the Hutterite population. By 1944 members were to some extent authorized to wear modern “high” shoes. In

1950–1953, Eaton and Weil [30] and Torrey [31] found a schizophrenia prevalence rate of 1.3 per 1000. A re-study in 1992–1993 by Nimgaonkar et al. [32] found 1.2 per 1000. There were only four cases of schizophrenia among $\approx 12,500$ Amish studied 1976–1980 by Egeland and Hostetter [33], that is circa 0.3 per 1000. The Amish and the Hutterites prevalence rates are less than 25% of the rates reported for rural areas in the United States in recent studies [28].

In the coldest climates people traditionally wore flat boots. The Saami live in Norway, Sweden, Finland, and the Kola Peninsula in Russia. The Swedish Census of 1930 [34] reports a prevalence of insanity in the Saami that was twice that in the general population. Andersen [35] found more acute psychoses in a Saami than in a non-Saami population. In 1944 Bremer [36] found a schizophrenia prevalence rate of 5.3 per 1000 in Berlevåg, an isolated fishing village in Northern Norway on Barents Sea predominantly inhabited by people of Norwegian ethnicity. A relative isolation from the main parts of Norway made them use Saami boots right up to the 1930s. Lynge et al. [37] found a higher prevalence of schizophrenia in the Greenlandic population compared to the population in Denmark. The traditional Greenlandic footwear is a sealskin boot, and as long as these were worn there probably was no schizophrenia in the population, older literature describes it as at least very uncommon.

In the warmest climates people traditionally went barefoot or used sandals. The almost complete absence of schizophrenia is noted in several reports from Africa before World War II [6], Torrey [28], in a review of prevalence studies, reproduces data from Ghana in 1984, 0.5 per 1000, and Botswana in 1986, 2.0 per 1000. In the Pacific Islands many observations indicated the absence of schizophrenia. There was a 20-fold difference in rates between some highland districts and some coastal districts, this could be explained by more contacts with the Western World and its fashions [38]. Surveys in Taiwan in three Chinese communities 1946–1948 [39] and in four Aboriginal tribes 1949–1953 [40] reported a schizophrenia prevalence rate of 2.1 per 1000 in the Chinese and between 0 and 1.1 in the Aborigines. Probably the use of modern shoes was more common in the Chinese, who mostly lived in the towns and were more influenced by Western fashions.

Other studies show the effects of people migrating from a region with less common use of heeled footwear to a region with more common use. The high prevalence of insanity in European immigrants in the United States was noted already

in the middle of the 19th century. Odegaard [41] found higher total admission rates of Norwegian immigrants than of native Americans in an asylum in Minnesota between 1889 and 1929. The admission rate for schizophrenia was also higher in Norwegians in the Minnesota asylum than in an asylum in Norway. White noticed that the prevalence of insanity in African-Americans increased when they migrated from the South to the North, and Ödegaard [42] mentions the immigration from Puerto Rico to New York City after World War II, where the frequency of schizophrenia in immigrants was nearly double that in native New Yorkers. Schizophrenia has been common among Irish immigrants to the United States [6], probably because they began to use heeled footwear. High rates of schizophrenia in African-Caribbean immigrants in Britain since the 1960s [43] higher admission rates in the second-generation than in the first-generation immigrants [44], and a morbid risk in second-generation siblings of patients with schizophrenia that is 3.0–6.2 times higher than in the first-generation ones [45,46], strengthens the possibility that the high rates are attributable to an environmental factor, probably that children in Britain learn to walk wearing shoes while children in the Caribbean go barefoot. High rates of schizophrenia has also been found in The Netherlands in immigrants of British-Indian and African origin from Surinam and the Netherlands Antilles, in immigrants from Morocco and Cape Verde but not from Turkey [47]. Turkish men have worn heeled footwear since the 15–16th centuries, West European styles since mid-19th century, women from the 1870s. High rates have also been found among immigrants to Sweden, especially from East-Africa [48].

Torrey [6] discusses the role of civilization/industrialization in the etiology of schizophrenia. The industrial revolution, which started in England in the middle of the 18th century, resulted in the 19th century in a GNP per capita which was nearly double that of the rest of Western Europe and the United States, not until the 1890s was England surpassed by the United States, whose economy grew dramatically after the Civil War. No other factor associated with this general economic development can explain the rapid increase in the prevalence of insanity/schizophrenia in Massachusetts during the 1830s and 1840s but the increased shoe production.

There probably is a linkage between an increase in space and time in the use of heeled footwear, and an increase in the prevalence of schizophrenia. A slowly rising epidemic in England, probably from the end of the 18th century, was followed by a more rapidly rising epidemic in the United States

from the 1830s, and then in Germany and Sweden. Such epidemics of schizophrenia could probably only have been caused by one and the same etiologic factor acting in populations with individuals genetically less adapted to the change. Changing symptoms and incidence, increasing age of onset, a change in course and outcome strengthen the idea of epidemics of schizophrenia. World, ethnic, and national dress are inter-related in today's global community, and modern studies of schizophrenia occurrence in different groups and different countries often find no great differences [49]. Differences found could be attributed to different time courses of prevalences in different groups.

Physiology

Lengthening contractions of the triceps surae muscles during walking results in synchronised barrages of impulses from the mechanoreceptors reaching the cerebello-thalamo-cortico-cerebellar loops where they increase cortical excitability [50]. The left and the right parts of the cerebellum are stimulated alternately. Stimulation of NMDA-type glutamate receptors leads to expression of synaptic proteins and modifications in synaptic and dendritic organization [51]. Using heeled shoes weakens the lengthening contractions and the stimulation of the receptors, and a decrease in cortical activity leads to a change in dopaminergic function thereby involving the basal ganglia-thalamo-cortico-basal ganglia loops, too [52–58]. Heath [59] found that electrode stimulation of the anterior parts of the cerebellum could improve functioning in schizophrenia. These parts are normally stimulated by impulses from stretch receptors in the lower extremities. Bicycling reduces depression in schizophrenia and this is probably due to the improved lengthening contractions of the triceps surae.

Involvement of different loops in different brain regions leads to different symptoms and signs [60–64]. The neuropathology of schizophrenia represents the anatomical substrate of aberrant functional connectivity [65]. Susceptibility genes for schizophrenia may have convergent effects on glutamatergic and other synapses [66].

According to Ledebt et al. [67] gait initiation starts when the child stands up and then begins to fall forward. The first few months after onset of walking are followed by a period of development of anticipatory behaviour participating in a finer tuning of postural and locomotor components of gait. White children reach independent walking at a

mean age of 11.6 months and black children at 10.9 months [68]. Jamaican infants walk earlier than infants from five European countries [69], the warm climate probably giving them a better chance to walk barefoot. A study from Philadelphia in 1979 [70] found that infants receive their first walking shoes at an average age of 8.1 months. Such shoes look quite flat but are provided with insoles that are somewhat thicker in the heel part, so as to function as heeled shoes.

The earlier in life children wear shoes the more vulnerable they may be as cellular proliferation and migration in the cerebellum does not cease until after the child begins to walk [71]. Degree of urbanization of birthplace or upbringing might be associated with the rate of schizophrenia and probably is a proxy variable for the use of shoes when the child begins to walk, urban children more often wearing shoes than rural children [72]. The seasonal variation of schizophrenia births [73] also could be explained by the use of shoes. A child born in January–March begins to walk about 11–12 months later, in December–March when its winter and cold and the child probably has the least chance to go barefoot. Birth deficits in the summer and fall months could likewise be explained by the better chance of going barefoot. Data from the British 1946 Birth Cohort [74] show that milestones of motor development, particularly walking, were delayed in children who went on to develop schizophrenia as adults. Another study found that the ages at learning to walk was related to subsequent incidence of schizophrenia and other psychoses [75]. Gait peculiarities in schizophrenia were noted already by Eugen Bleuler.

Schizophrenia is supposed to have its origins in developmental processes that transpire prior to the onset of clinical symptoms [1], but it is difficult to explain how an early static lesion could lead to clinically apparent schizophrenia twenty years later. A continuous faulty stimulation of the cerebellar loops during many years, often starting when the child begins to walk, may, after at least ten years, result in clinically apparent schizophrenia. Norwegian immigrants [41] spent at least 10 years in the United States before they were admitted to an asylum, that is, they had to use heeled footwear for at least so many years. Immigrants with schizophrenia or other non-affective psychoses spent a mean of nine years in Sweden before first contact with psychiatry [48]. That continuous faulty stimulation leads to schizophrenia implies progressive brain pathology, and Kraepelin originally described dementia praecox as a progredient disease, and considered it to be a self-inflicted poisoning. The patients continued to wear heeled

shoes in the asylums, and the continued faulty stimulation led to progressive degeneration.

The onset of schizophrenia during the adolescence may be related to the maturation of the dopamine controlled basal ganglia loops during these years [76], which is modulated by gonadal hormones [77]. Reduced glutamatergic stimulation of the cerebellar loops may not have an apparent effect until puberty and early adulthood, when these loops mature [57,76].

Conclusions

Many data suggest an association between the use of heeled footwear and schizophrenia and they could probably be questioned in many instances. I have however not been able to find any contradictory data. One possibility would be the existence of young patients not being able to use their legs during many years and yet having schizophrenia. I have never seen such a patient.

I suggest that there is an association between the use of heeled footwear and schizophrenia. Cross-sectional prevalence studies should be performed, e.g., in immigrants from regions with less use of footwear, or for example in India where different groups of people begin to wear shoes at different ages.

The effects of the use of heeled and flat shoes during shorter or longer periods of time on cortical excitability [54], and on connectivity in cerebellar and basal ganglia loops [52,55] could be studied in patients with schizophrenia. A normalization of patterns would indicate the importance of the proposed neural pathways in the pathophysiology of schizophrenia.

Patients could be recruited to clinical trials of the effects of using only flat shoes as long as possible on symptoms and cognitive deficits.

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