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IS WORK EXPOSURE A RISK FACTOR FOR PLANTAR FASCIITIS?

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Background *Plantar fasciitis is a common foot problem that is hypothesized to arise from microtrauma to the foot. There is abundant literature on the adverse health effects of repetitive work, forceful activity and static positioning on the development of upper extremity musculoskeletal disorders. Studies on the etiology of lower extremity injuries are few, in particular, those relating the standing posture and walking. About 30 to 40 % of the working population either stand or walk most of the day, and yet we know little about the adverse health effects of one of the most common work activities.*

Methods *A qualitative systematic review of the literature was conducted on studies relating standing and walking to foot pain and plantar fasciitis.*

Results *Two cross-sectional studies and one case-control study are identified during the search. The odds ratio for the case control study comparing plantar fasciitis and frequent standing was 1.9, 95% CI, 1.0-3.62 (Gill et al., 1996). The cross-sectional study prevalence relative risk (PRR) relating foot pain to standing and walking in the first study (Buckle et al., 1986) was 6.84 95% CI, 2.91-16.11 and the second study PRR was 2.36 95% CI, 1.07-5.23 (Ryan, 1989). Support for a dose response relationship was present in the Ryan (1989) and Gill et al., (1996) studies.*

Conclusions *Prolong standing and frequent walking pose as risk factors in the development of foot pain including plantar fasciitis. Other risk factors associated with foot pain included obesity, recreational causes, hard floors/ hard-sole footwear and systemic diseases such as gout.*

KEY WORDS: *standing; foot pain; plantar fasciitis; occupational injury; repetitive strain injury; review; walking; ergonomics.*

INTRODUCTION

Plantar fasciitis, a common orthopedic problem seen in the primary care giver's office is usually reported as a pain in the rear, medial foot on the plantar surface of the foot (Sternberg et al. 1992). Plantar fasciitis is said to be a result of "microtrauma" to the fascia or a form of repetitive strain injury (Scheppis et al., 1991). Much has been written on upper extremity and low back cumulative trauma disorders or repetitive strain injuries but there has been little attention directed to lower extremity disorders arising from work. The United States National Institute of Occupational Safety and Health (NIOSH) publication reviewed over 40 epidemiological studies on physical factors and their relationship to neck and shoulder musculoskeletal disorders (MSD) (Bernard, 1997). There is evidence for a causal relationship between "highly repetitive work" as well as "forceful work" and the development of neck and shoulder MSD. There is strong evidence that prolong, high static loads or extreme working posture can cause neck and shoulder MSD.

Among the Danish general working population, 25% worked in the standing position 21% walked most of the day (Hansen et al., 1998). Prolonged standing at work in a cross-sectional study was associated with the development of chronic venous insufficiency (Tomei, et al., 1999). They found that among the 336 workers, those who stood for more than 50 percent of a shift there was an increased likelihood of developing chronic venous insufficiency. Do jobs that require a person to stand or to walk on a constant basis at work, sometimes bearing a load and occasionally to run, create musculoskeletal stresses in the lower extremity, in particular, the plantar fascia?

Epidemiology

A unique survey of the epidemiology of plantar fasciitis using internet respondents was reported by Scott Roberts in 1998 in his web site www.heelspur.com. Among 255 respondents 62% were female and 70% of respondents were between 30 to 49 years of age. In another survey by the same author, 37% of the respondents (n=1196) had the condition for less than or equal to six months. Six percent had plantar fasciitis for greater than 48 months. The study was limited by the self-selected sample who had access to internet connections and who were willing to fill a questionnaire on the internet.

The demographics of an out-patient clinic study showed a similar distribution of 60% female to 40% male among 411 patients with plantar fasciitis (Gill et al., 1996). The mean age of the male patients was 49.0 SD 12.6 and female patients was 46.7 SD 12.4. The range for all patients was 15 to 85 years of age. In a smaller case series, 57% of the 116 patients are between 40-60 years of age with an almost equal number of males to female (Furey, 1975).

Anatomy

The central part of the fascia is thickened to form the plantar aponeurosis. The aponeurosis arises from the calcaneal tubercle at the rear of the foot and proceeds anterior to the forefoot to form part of the longitudinal arch; it inserts into the base of each of the proximal phalanx. The central segment is thick and the lateral and medial portions are thin (Mitchell et al., 1991, Moore, 1985). From the central part of the aponeurosis vertical septa extend deeply into the foot to form the lateral, central, and medial compartments. Pain sensation in plantar fasciitis follows the medial compartment. There are four layers of muscles in the foot. There are two neuro-vascular layers in the foot: the superficial set is located between the first and second muscular layer and the deep set is between the third and fourth muscular layer. The tibial nerve divides posterior to the medial malleolus into the medial and lateral plantar nerves, which supply the intrinsic muscle of the foot. The foot arteries are from the posterior tibial artery, which winds around the medial malleolus and divides deep to the medially located abductor hallucis into the medial and lateral branch; it follows the course of their similarly named nerve (Moore, 1985).

Biomechanics and Pathogenesis

The two main phases in walking are the stance and the swing (Adelaar, 1986). The stance phase comprises of 65% of a walk cycle and consists of right heel strike, followed by mid-stance, foot-off and returning to left heel strike. The right leg is then put into the swing phase for 35% of the walk cycle. The difference between walking and running is that between the stance and the swing phases in running, there is a "float" phase where both feet leave the ground. The anticipated force on both feet upon contacting ground would, therefore, be greater in running than walking. As the heel strikes the ground, the plantar fascia together with the foot intrinsic muscles set the foot into action with gradual pronation, which is followed by supination at toe-off. The walking movement exerts repetitive stress on the plantar fascia.

The plantar aponeurosis absorbs the direct forces generated during heel strike, foot plant and take off (Brown, 1996). The plantar aponeurosis is subjected to steady pressure and tightening of the aponeurosis at the medial longitudinal arch (Adelaar, 1986, Kwong, 1988). Studies on cadavers showed that the plantar fascia together with other plantar ligaments and the calcaneo-navicular or spring ligament rather than the muscles provided the major arch support (Huang et al., 1993). The attachment of the plantar fascia, specifically at the calcaneal bone is subjected to mechanical stress.

Standing is a form of isometric, static activity in which the muscle and ligaments are subjected to prolonged low intensity load, stressing vascular, bony and vascular tissues (van Dieen et al., 1995, Westgaard, 1988). Static contraction is associated with a marked decrease in blood flow to the muscle. Fatigue is said to arise from impaired blood flow resulting in a mismatch between energy supply and energy demands (Sjogaard et. al., 1988). Jonsson (1988) suggested that the static work should not exceed 5% maximum voluntary contraction (MVC) for work of long duration. Endurance limits for holding for more than an hour may be as low as 8% MVC.

Pure static loading is rarely seen in human activities; it refers to continuous isometric contraction at one load level. Typically, there is intermittent muscle activation of various muscle groups in the feet and legs even when standing on a relatively small platform.

Other studies have found that foot volume increased by 1.4% after 240 minutes of standing when the temperature was kept at 28 degrees centigrade and the footprint increased by 6.7% (Rys et al., 1994). In addition, the foot did not swell evenly across its length: swelling in the instep increased 8.6% with no change in the length of the foot and swelling increased 3% at the widest part of the foot in the fore-foot (Rys et al., 1994). Plantar fasciitis associated pain is present in the medial foot adjacent to where the instep is located.

Force plates may be used to measure the pressure exerted by different parts of the foot on the ground. During standing, the body weights of most people are distributed more on the heels than the balls of the feet (Rys et al., 1994).

Work-rest schedule affects the swelling of the distal lower leg and subjective ratings of discomfort (Van Dieen et al., 1998). A group of 12 poultry inspectors was put through several experimental settings: 60 minutes work, 15 minutes rest (60/15), other settings of work/rest duration in minutes were 45/15, 30/15, 30/ 30. An optical leg volume meter was used to measure swelling in the lower legs. The volume of the distal leg (ankle area) was significantly increased in the 60/15 schedule compared to other schedules with a mean swelling of 2.4% at the end of 4 hours. On a 5-point scale of discomfort ("1" being least discomfort and "5" being most discomfort), the 60/15 condition produced discomfort rapidly and arrived at a mid-point discomfort level by 2 hours out of the 4 hours experimental shift. In contrast, the midpoint discomfort level was reached in the 30/15 and 45/15 conditions towards the end of the session or at the 4th hour. The discomfort level was rated at "1" at the end of the 30/30 session.

Diagnosis

The person typically complains of pain in the medial rear foot, greatest in the morning upon arising from bed. There is heel pain when getting up from a chair after sitting for a period of time. There is maximal tenderness at the medial calcaneal tubercle (Schepsis et al., 1991). The medial rear foot X-rays may show heel spurs but the appearance of spurs is not always seen in plantar fasciitis. A clinical series described 87 painful heels with calcaneal spurs and 75 painful heels with no spurs (Lapidus et al., 1965). Those with plantar fasciitis had thickening of the plantar aponeurosis in high-resolution ultrasound studies (Cardinal, 1996; Gibbon, 1999). Abnormal plantar aponeurosis echogenicity was noted in 78% of those with plantar fasciitis and 24% had calcaneal spur. Magnetic resonance imaging (MRI) revealed thickening of the plantar fascia with increased intrasubstance T2-weighted signal. Edema, if present, was seen as diffusely increased T2-weighted signal in the subcutaneous tissue (Hochman et al., 1997). MRI can detect diseases that may be confused with plantar fasciitis. Early stages of calcaneal fracture can be distinguished from plantar fasciitis. Pathology studies of plantar fasciitis show fibroblastic proliferation and chronic granulomatous tissue (Pfeffer, 1995).

Differential Diagnosis

Heel pain may arise from many different causes besides plantar fasciitis. (1) Trauma may cause calcaneal fracture. (2) The fat pad located under the calcaneus may atrophy over time and may also be injured in a puncture wound. (3) Post-traumatic osteoarthritis may develop after a joint injury. (4) Tarsal tunnel syndrome results from compression of the tibial nerve in the tarsal tunnel, a fibro-osseous space located behind the lateral malleolus and that also courses along the medial foot. Typically there is a history of trauma, sometimes of a minor nature to the ventral foot. Criteria for the diagnosis of tarsal tunnel syndrome include: pain and paresthesia in the foot, a positive Tinel's sign and a positive electrodiagnostic study (Lau et al., 1999). (5) Systemic diseases may affect the foot tissues directly or act as risk factors for developing plantar fasciitis. Rheumatoid arthritis, ankylosing spondylitis, sexually acquired reactive arthritis and gout may result in heel pain (Schepsis, et al., 1991, Rich E et al., 1996). (6) Achilles tendonitis and tenosynovitis of the foot are differentiated by the anatomical positions of those structures and may occur concurrently with plantar fasciitis.

Factors Associated With Foot Pain

There are several reviews on factors causing foot pain (Brown, 1996, Cornwall et al., 1999, Kwong et al., 1988, Schepsis et al., 1991, Satterthwaite et al., 1999, Singh et al., 1997). The summary below attempts to provide a more detailed description of those factors.

Obesity

Body mass index (BMI) is equal to weight (kilograms)/ height squared (meters). A BMI of between 20 to 25 is associated with the least amount of adverse health effects (for example, cardiovascular diseases) compared to those below and above that range (Health and Welfare, Canada, 1988). Roberts' (1998) internet survey of individuals with plantar fasciitis (n=725) showed that 60% have BMI of over 26 (Table I).

Table I. Body Mass Index of Respondents with Plantar Fasciitis.

Below 17.5 (very thin)	0%
17.5 to 21	7%
21+ to 26	33%
26+ to 31	31%
31 to 36 (obese)	18%
above 36	11%

Adapted from Roberts (1998)

The people who participate in marathon running are self -selected. Those runners in the lowest BMI of less than 19.5 or more than 27 both have increased injury rates (Marti et al., 1988). In a case-control study, weight was measured but not height (Gill et al., 1996). Table II presents the finding that plantar fasciitis patients were heavier than controls.

Table II. Weight in Pounds in Cases with Plantar Fasciitis and Controls.

	Cases	Control
Less than 100 lbs	0	4
100 to 150 lbs	95	136
150 to 200 lbs	195	168
More than 200 lbs	200	92

Distribution significantly different between plantar fasciitis patients and control patients, P=0.0007, chi-square=14.43 (adapted from Gill LH et al., 1996)

A chart review of a clinic's plantar fasciitis patients (N=77), showed the male: female ratio was 36:41 and the mean age was 47.1 years (range 23 to 74 years of age). Based on age standardized tables, significantly more men (28 of 36 or 77.8%) had weights above the 50^{th} percentile than the expected 18 (P=0.0009) (Hill et al., 1989). Similarly more females, 36 of 44 or 87.8% had weights above the 50^{th} percentile than the expected 22 (P=0.0001).

Recreational Factors

Van Mechelen (1992) reviewed literature on running injuries known up to 1990. He noted that with the popularity of running, there had been an increase in number of acute and chronic running injuries. In Holland, the injury rate was estimated to be 3.6 injuries per 1000 hours of participation. Between 55 to 65% of injuries were felt to be from overuse causes. Knee injuries accounted for 25% of cases and feet injuries accounted for up to 22% of injuries.

The factors associated with injuries included previous injury, lack of running experience, running to compete and excessive running distance. In a survey administered as part of a 16 km marathon the longer a runner jogs per week, the higher the injury rate. For example, for those subjects who ran over 50 km, 27.8% had injuries (Marti et al., 1988).

Anatomical variations such as foot arch height, pronation of the subtalar joint, and leg length inequality did not predict who will suffer from plantar fasciitis (Warren 1984). A similar retrospective study involving 304 runners described a correlation between arch height and shin injuries; leg length difference was associated with back, ankle, and foot injuries (Wen et al., 1997).

Foot injury is seen in other stressful sporting activities. An exaggerated manner of foot movement is used in Japanese fencing or "kendo". Rapid forward movement is made with the foot during the attack mode. Force plates measurement showed that the foot force hitting the floor was equal to an impact of four times body weight. Four out of the five women kendoka or fencers developed plantar fasciitis over the wooden floor laid over concrete (Nunn et al, 1997).

The epidemiology of walking injuries is meager compared to research on running injuries. Elderly subjects (60 to 79 years of age) in an experimental study were subjected to 26 weeks of three times a week of treadmill work out. An objective was to achieve heart rates of 60 to 65% of maximum heart rate (moderate intensity) and 80 to 85% of maximum heart rate (high intensity) (Carroll et al. 1992). The maximum walking time was up to 40 minutes. Over the 26 weeks, 4 out of the 27 moderate intensity group and 3 out of the 18 in the high intensity group developed musculoskeletal injuries. Two developed foot injuries, one from each group; one had plantar fasciitis and the other had an aggravation of an arthritic condition.

Systemic Disease

In a series of hotel workers with plantar fasciitis, hyperuricemia was present in 16 of the 171 workers (9.4%) (Lapidus et al., 1965). In another clinical case series of 116 patients: 14 had rheumatoid arthritis, 4 had gout and 1 has spondylitis (Furey, 1975).

Floor Surfaces and Foot Insole

The interface between the foot and floor interface may be in many forms such as hard or soft footwear on a soft carpeted floor or concrete surface. Repeated standing or walking involves loading of the foot-floor interface (Goonetilleke, 1999). Industrial mats have been used to counter the adverse health effects of prolong standing. Various methods have been devised to measure comfort of the different standing surfaces including mat. Redfern (1995) used a psycho-physical rating to determine comfort. Soft mat was perceived to be more comfortable than hard concrete floor. "Very soft" mat was, however, deemed to be more uncomfortable than hard floor, perhaps, from an inability to make subtle foot movements resulting in less venous return and hence more edema. In another experiment, soft sole shoes were more comfortable than hard sole shoes (Zhang et al., 1991). In addition to the effects of shoes and mats, leg edema increased with time standing (Hansen et al., 1998). There was "pooling" of blood in the foot after standing for a period of time. The swelling increased with temperature rise and if clogs (hard sole shoe) rather than enclosed soft-sole shoe was worn. Hard sole shoe standing on very soft mat was associated with the most foot swelling. Soft sole shoe allowed dorsiflexion of the foot joints that promoted the venous pump in returning blood to the heart and may reduce edema. The rigid hard shoe did not allow dorsiflexion of the foot and hence did not help the venous pump. The very soft mat caused subtle reduction in movement patterns such as from foot shuffling resulting in increased foot edema. The standing/walking work compared to standing work alone was associated with less foot swelling. Walking promoted the venous pump and reduced foot edema. A person wearing soft sole shoes versus hard shoes during standing/walking experiment reduced foot swelling from 2.2% to 1.2% or about half of the foot swelling.

Another factor that affects the foot is heel impact against a floor surface. Heel impact was significantly greater using hard shoes compared with soft sole shoes (Hansen et al., 1998). Hard surfaces also cause greater heel impact than soft surfaces.

A case control study compared the type of floor walked on most of the time among plantar fasciitis patients and controls and found that more plantar fasciitis patients walked on hard floors than controls (Table III, Gill, 1996).

Table III. Floor Walked on Most of the Time Among Patients with Plantar Fasciitis and Controls.

	Cases	Controls
Hard	212	161
Soft	21	38
Variable	178	199

Distribution significantly different between plantar fasciitis patients and controls, P=0.002, chi-square=12.84 (adapted from Gill LH et al., 1996).

Military service

Army recruits are subjected to intense physical training. Three hundred and fifty Australian army recruits were randomly assigned to either a running or walking group (Rudski, 1997). Over the 12-week course, 41.3 hours per week was spent in physical exercises. The pace of marching was increased to a maximum of 7.5 km per hour. A load of 16.2 kg was carried initially. At week 5 an additional 2.5kg was added per week. The rate of injury was 52.9/100 recruits in the walking group and 60.5 among the running group. The lower limb was involved in 25.3% of injuries in the walking group and 41.7% in the running group. The knee was involved in 8.8% of the walking injuries compared to 18.8% of the running injuries. Both walking and running groups passed the five kilometers run test with no difference in performance. Two recruits in the running group stopped training because of foot pain. The author suggested that a walking regimen was associated with less lower limb injuries than a running regimen.

REVIEW OBJECTIVES

This paper will systematically review the literature on standing as a risk factor in the development of foot pain and plantar fasciitis and perform a qualitative analysis of relevant studies. The question that is asked is: “Is prolong standing associated with foot pain and more specifically plantar fasciitis?”

METHODS

Search Strategy

The search strategy to identify original and review literature included:

1. A Medline and Nioshtic search in May, 2000 using the key words: plantar fasciitis, foot pain, upright posture, standing, walking injuries, running injuries, occupational lower extremity injuries.

2. Internet resources: Ergoweb.com, Medscape.com, MD Consult.com, Duke University Occupational Medicine Forum, ergonomic link sites of the Quebec IRRST and the Canadian Center for Occupational Health and Safety.

3. Textbooks in Occupational and Physical medicine and a hand and internet search of abstracts of recent journals relating to the foot and ergonomics.

4. Bibliographies of articles searched.

5. Files of colleagues and the clinic library.

Selection Criteria

All studies in English that related occupation to working in the standing position were chosen. Inclusion criteria included: (1) there is a study and a control group; (2) exposure is defined; (3) outcome is either foot pain or plantar fasciitis.

The quality of studies was considered to be higher: if there are high participation rates (>70%), health outcome is assessed by physical examination, exposure is assessed independently and if health and exposure status is blinded (Bernard et al., 1997). "Blinding" is necessary to prevent bias in the assessment of outcomes from the expectations of either the investigator or subject.

Odds ratios for case control studies and prevalence relative risk for cross-sectional studies and 95% confidence intervals were calculated using Epi-Info 2000 from the Center for Disease Control, Atlanta.

RESULTS

Five studies were identified for initial consideration. One study, which did not meet inclusion criteria, was a case series that had no control group; the majority of the plantar fasciitis patients spent their working days on their feet (Lapidus et al; 1965). Another study was rejected for the same reason of not having a control group; the study described the musculoskeletal health of supermarket workers (Wells et al., 1990). The other three studies met the inclusion criteria. Two were cross-sectional studies (Buckle et al., 1986 and Ryan GA, 1989). One study was a case control study (Gill et al., 1996). None of them met all the four "quality criteria"; the Ryan (1989) and Gill (1996) studies met three criteria (Table IV). Buckle (1986) study met two criteria.

Table IV: Epidemiological Criteria to Examine Threats to validity

Study (first author and year)	Participation Rate >= 70%	Physical Examination	Blinding of Investigator to Exposure Status	Independent Exposure Assessment	Confounders Measured
Ryan, 1989	Yes	No	Yes	Yes	Age, sex
Gill, 1996	Yes	Yes	Yes	No	Age, sex, weight
Buckle, 1986	Yes	No	Yes	No	Sex

The study findings are summarized in Tables V and VI. All three studies found elevated odds ratios and relative risks above 1.0 and a statistically significant relationship in the strength of association between standing or "being on feet all day" and the presence of foot pain or plantar fasciitis.

Table V: Summary of Study Design, Population, Exposure and Outcome

	Ryan, 1989	**Gill, 1996**	**Buckle, 1986**
Design	***Cross-sectional***	***Case-control***	***Cross-sectional***
Study Subjects	508 supermarket staff: checkout 180 grocery 127 store and night fill 29 specialty 119 management office 53	451 patients with plantar fasciitis	342 department store and 85 supermarket workers
Control Subjects	Internal controls	400 randomly selected patients with orthopedic problems other than plantar fasciitis	Internal controls with no regular pain or discomfort in feet
Outcome	Self-administered questionnaire. Case defined as regular pain or discomfort in feet. Regular = at least once per week for 2 months.	Plantar fasciitis as determined by physician diagnosis.	Self-administered questionnaire. Case defined as having regular pain or discomfort in feet.

	Ryan, 1989	Gill, 1996	Buckle, 1986
Exposure	Two observers sampled each job title for a period of 30 minutes.	Self-reported: rarely on feet (desk job), sitting/standing job, on feet most of the day.	Self-reported: percentage of day spent standing, sitting, kneeling and walking.

Table VI. Summary of Reviewed Studies on Standing and Foot Pain

Study	Comparison for Foot Pain	Odds Ratio/Prevalence Relative Risk	95% CI
Ryan, 1989	90% standing (checkout) vs. less than 60% standing (grocery, store, night fill)	2.36[a]	1.07 – 5.23
Gill, 1996	Mostly on feet all day vs. rarely on feet	1.9[a]	1.00 – 3.62
	Mostly on feet all day vs. standing or sitting during day	1.47[b]	1.09 – 1.98
Buckle, 1986	Standing over 30% of day vs. standing less than 30% of day	6.84[b]	2.91 – 16.11

CI = Confidence Interval
a = $p < 0.05$
b = $p < 0.01$

Ryan (1989) plotted the prevalence of symptoms of ankle/foot pain against the percentage of time spent standing. The slopes of the regression lines were different from zero for the ankle and foot: R squared=0.951, t=8.79. p=0.001. There was a threshold at about 45-50% time spent standing for regular symptoms of the ankle and feet. For low back symptoms, the threshold was about 25% of time spent standing.

DISCUSSION

Two cross-sectional and one case control studies were identified in this review. None of the studies met all the four criteria for study quality (table IV). All the studies had high participation rates leading to less risk of selection bias. Physical examination was not performed in the cross-sectional studies (Buckle and Ryan). Blinding of the examiner was assumed in the questionnaire studies because the examiner generally could not bias a subject's response unless inappropriate instructions had been targeted at specific groups. The questionnaires in all the studies were administered to all subjects with no special instruction. Only one study (Ryan) provided an independent exposure assessment. Exposure assessment beyond job titles and industry worked in is usually not available in case control studies. The case control study identified (Gill) did not even have a job title.

Two of the studies measured "foot pain" (Buckle and Ryan) and one measured plantar fasciitis (Gill). "Foot pain" may mean any of the possible diagnosis described under the "differential diagnosis" section described earlier. Some of the pain reported may be plantar fasciitis but the percentage or workers who had the condition is unknown because of a lack of physical examination.

The cross-sectional studies are limited by survival bias; those who have developed plantar fasciitis may have left the workplace leading to an underestimation of risk among those employed. Secondly, the temporal relationship of foot pain before or after starting work at a location is not known in a cross-sectional study.

Causality

Whether a specific factor is causally associated with a condition can be assessed using a set of criteria such as the Bradford-Hill's criteria (Hill, 1965). Among the nine criteria used, only the criterion of temporality where the cause must precede the effect is inarguable (Rothman et al., 1998). Table VII presents some of the criteria; all three studies show a positive association between standing and developing foot pain/plantar fasciitis. A strong association is more likely to be causal than weak associations (Hill, 1965).

Table VII: Evidence for a causal association between excessive standing and foot pain/plantar fasciitis

	Ryan 1989	**Gill 1996**	**Buckle 1986**
Strength of relationship	Yes	Yes	Yes
Dose Response	Yes	Yes	?
Temporal relationship	?	?	?
Ruled out competing plausible hypothesis	No	Yes	Yes

?: *could not be assessed because of study design*

The next criterion is a dose response relationship. As the intensity of a dose increase, there is a corresponding increase in effect. It is clear from the military recruit study (Rudski, 1997), that increasing the stress on the lower extremity from walking to running resulted in a greater number of injuries to the lower extremity. Increasing the distance run per week for marathon runners increased the risk of injuries (Marti, 1988). Increasing the time spent standing increased foot volume and discomfort and potential damage to the plantar fascia (Hansen et al., 1998, Van Dieen et al., 1998). Ryan's (1989) regression analysis showed that the prevalence rate of symptom in the foot/ankle increased with the amount of time standing. Similarly, Gill's study (1996) revealed that the odds of developing foot pain was higher among those patients who stood all day compared those who sit and stand during the day. The latter group in turn had higher odds of developing foot pain than those who had "desk jobs" who rarely stood on their feet.

The causative factor must precede observed effect. The "time-relationship" is an absolute criterion. The case control and cross-sectional studies reviewed do not permit an evaluation of this criterion.

The fourth criterion is one of plausibility. Standing, walking, and running require an upright position such that there is pressure exerted on the plantar fascia, nerve and blood vessels. The standing position resembles a "static" type of work involving static loading whereas walking and running are both "dynamic" type of work. It is well known in studies of the upper extremities that static loading or repetitive work can cause musculoskeletal disorders (MSK) (Bernard, 1997). It is plausible that the lower extremities subjected to static loading are susceptible to the development of (MSK). In addition, extensive research on the upper extremity MSK has provided evidence of a causal relationship between highly repetitive work as well as forceful work and neck/upper back and shoulder disorders. One can also argue that it is plausible that excessive walking or sometimes running is a form of highly repetitive and forceful work of the lower extremities.

When repeated observation of association is consistent in different populations and different settings using different research design there is greater likelihood of a causal relationship (Rothmans et al., 1998). The three studies reviewed from three distinct populations and three different continents employed two different study designs showed a consistent, positive relationship between standing/upright position and foot pain/plantar fasciitis.

The criterion for coherence notes that the proposed cause and effect relationship does not conflict with what is known of the natural history and biology of the disease. There is a great deal of similarity to the plausibility criterion; the two criteria are mirror images of each other where one seeks general data to support and the other criterion is concern that there are no conflicting data to refute the relationship (Rothman et al., 1998). The data from biomechanics and physiology of the upright position in standing, walking and running as discussed under the "plausibility" criterion supports the coherence criterion. There is no suggestion of lack of coherence with known data.

Standing and walking are the two most common occupational activities involving 30 to 40 percent of time at work of the working population. The vital distinction between walking at work and leisure is that at work, walking does not usually cease when the person feels uncomfortable or tired, walking may have to end at the end of a shift or when a defined job is completed. The next day, the same routine will be repeated for up to five to seven days a week depending on the length of the working week

Occupational injuries may be caused directly by an exposure. Alternatively, injuries may also arise in conjunction with an underlying health and/or life-style condition through an aggravation process. Other risk factors of foot pain and plantar fasciitis have been discussed earlier such as obesity, recreational causes and systemic diseases. This paper provides a description of risk factors of foot pain and not whether foot pain or plantar fasciitis is work related. Work relatedness is dependent on review of individual cases including asking if there is a significant contribution of the work exposure to the disease (Barth et al., 1982).

CONCLUSION

There is evidence from the reviewed biomechanical, physiological, experimental and epidemiological studies that met most of the causality criteria to conclude that prolonged standing and walking are risk factors in developing foot pain including plantar fasciitis. Other risk factors identified included obesity, recreational causes, hard floors/ hard-sole footwear and systemic diseases such gout. Further studies using various designs are needed to adequately define exposure levels in terms of duration, repetitiveness, force and intensity; as well as specific descriptions of health conditions and controlling for confounding factors. The final product is the development of work practice guidelines and prevention of injuries.

ACKNOWLEDGEMENTS

The author thanks: Judy Chow, CMS (Administrative Assistant), Lori Brown, RN, BScN, (Occupational Health Nurse), Brian Gibson, MD, CCFP, FRCPC (Occupational and Environmental Health Consultant), Syed Naqvi, PhD, CPE (Ergonomist) and Andy King (Executive Director) of the Occupational Health Clinic for Ontario Workers (Toronto); Dr. Donald Cole of the Institute for Work and Health, Ontario, and Lee Ciupa (Administrative Assistant) of the Lakeshore Area MultiServices Program, Etobicoke.

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