Therapeutic concept and relapse prophylaxis for Achilles tendon problems in athletics

© by IAAF
24:2; 21-31, 2009

By Susanne Kroesche

ABSTRACT

Achilles tendon problems comprise a complex of complaints that are widespread in sport, particularly among athletes in the running and jumping events. The influence of motion, the specific morphology of the Achilles tendon and the surrounding muscles, and the effects of these factors on the development of typical Achilles tendon problems are poorly understood. Such aspects are raised in sport medicine and biomechanics publications but are not always referred to in coaching publications. The purpose of this article, which is based on an extensive review of the relevant literature, is to provide a practical reference for coaches and athletes. It begins with a brief description of the biomechanics of the Achilles tendon and then covers the main problems to affect the Achilles tendon – ruptures and achillodynia – as well as the mechanisms at work in an Achilles tendon injury. It concludes with a discussion of the factors that must be taken into account by coaches and athletes in the prevention of Achilles tendon injuries: intrinsic, extrinsic, training methodological and sport medical. An accompanying article details how to plan and structure therapeutic programmes so that the athlete can return to competitive sports as soon as possible without the risk of follow-up injuries.

AUTHOR

Susanne Kroesche is a graduate of the German Sport University in Cologne and is currently the head of training in a sport therapy centre in Limburg, Germany. After finishing her career as a heptathlete she worked in several institutions as a therapist.

Introduction

Achilles tendon problems comprise a complex of complaints that are widespread in sport, particularly among athletes in the running and jumping events. Various authors report an increase in Achilles tendon problems in the last 30 years (SEGESSER et al., 1980; JÒSZA et al., 1989; JUNGMICHEL & NAWROTH, 1989; GROSJEAN & DEJUNG, 1990; LOHRER, 1996; MAYER et al., 2000). In running, the number of Achilles tendon injuries comes to 5-18% of all injuries (ULREICH et al., 2002).

The influence of a motion, the specific morphology of the Achilles tendon and the surrounding muscles, and the effects of these factors on the development of typical Achilles tendon problems are poorly understood (ARNDT, 1997). The consequences of this knowledge gap in athletes and coaches include late diagnosis of clinical symptoms

Table 1: Tensile loading at the Achilles tendon in various activities (N= Newton)

Sport	Tensile Loading	Author	Year
Running	5,880N	CARLSÖÖ (according to Ljungqvist 1968)	1968
Running	3,700N	BURDETT	1982
Sprinting	8,830N	CARLSÖÖ (according to Ljungqvist 1968)	1968
Sprinting	7,000N	BURDETT	1982
Long Jump	14,700N	HEGER	1966
Long Jump (8.40m)	14,715N	WEINECK	1997
High Jump	11,800N	HEGER	1966
High Jump (2.30m)	11,772N	WEINECK	1997

right up to ruptures of the Achilles tendon, which are being found more and more frequently (LOHRER, 1996). Moreover, this understanding is of great importance for the prevention of problems and for planning the training to accompany therapy when problems occur.

In this context it is interesting that such aspects are raised in sport medicine and biomechanics publications but are not always referred to in the relevant coaching literature such as the frame training plans of the German athletics federation.

The purpose of this article is to provide a practical reference for coaches and athletes. It begins with brief descriptions of the biomechanics of the Achilles tendon then covers the main problems to affect the Achilles tendon and the mechanisms at work in an Achilles tendon injury before concluding with a discussion of the factors that must be taken into account in the prevention of Achilles tendon injuries. An accompanying article details how to plan and structure therapeutic programmes so that the athlete can return to competitive sports as soon as possible without the risk of follow-up injuries.

Biomechanics of the Achilles Tendon

The main functions of all tendons are a) the storage of elastic energy and b) the transfer of force between muscles and bones (GREGOR, 1988). The ability to store elastic energy primarily depends on the tendon material and its mechanic loading capacity. The transfer of force is influenced by the mechanics of the joint, as well as by the force repercussion of the joint mechanics.

The Achilles tendon is marked by low flexibility and high tensile strength (ARNDT, 1976). In fact, it is the strongest tendon in the human body. FRANKE (1990) reports that the tear resistance value of the Achilles tendon is 680kg for static loads and 930kg for dynamic loads. However, a number of authors have shown that within the scope of sport motions there are forces at the Achilles tendon that far exceed the strength limits found in tests on dead material or in animal experiments. For example, KOMI (1990) states a maximum load on the Achilles tendon in running of 9,000N (N= Newton) or 12.5 times the body weight. BURDETT (1982) has measured a load range of 5.3 to 10 times the body weight and SCOTT & WINTER (1990) report measurements in the internal anatomical structures of 6.1 to 8.2 times body weight. Table 1 gives an overview of calculated tensile loading at the Achilles tendon in various athletics-related activities by other authors.

That such peaks are regularly tolerated without rupture or other injury is primarily due to the elastic qualities of tendons, which are able to store elastic tensile energy in relatively large amounts and to release it again quickly (HERZOG & LOITZ, 1994). Study of animals has shown that in cyclic motions such as running, the muscle-tendon complex is stretched by a contraction of the muscle and tensile energy is built up. However, the "deformed" tendon material is able to release the energy almost totally as soon as the tension diminishes. This quality enables a biological system to produce high speeds or jumping performances with relatively low in energy.

Equivalent studies are relatively rare with human beings. However, FUKASHIRO (1995) examined the energy storage of human tendons in various forms of jumping. The amount of energy stored in the Achilles tendon was measured in squat jumps, counter movement jumps and hopping. The results showed that the highest value was reached in rhythmic hopping - 34% or 17.5J (J= Joule). The measured values for squat jumps were 23% or 7.9J, and for counter movement jumps 17% or 6.2J. This shows that an increased amount of energy can be stored in the Achilles tendon by stretching the muscles. The author also found that:

- Stretching over longer duration reduces the loss of energy,
- Larger tendons (with more tendon material) can store more energy,
- Longer tendons slow down the transfer of energy and hence make coordination more difficult,
- Shorter tendons transfer forces more quickly and with a smaller amount of energy loss.

The role of the Achilles tendon is to enable plantar flexion to take place in the ankle joint. This flexion has a range of 30° to 50°, starting at a 0° neutral position of the foot. Of this movement, 95% takes place in the upper ankle joint (KAPENDJI, 1992; LUNDBERG, 1989). Plantar flexion is accompanied by a supination, which is smaller due to the fibular ligaments and can take some of the strain off the Achilles tendon (SEGESSER, 1974). In this context, it is important to note that the centre of the tendon insertion is located slightly medially of the joint centre. This results in an inversion of the *os calcaneum*. Additionally the twisted fibre bundles of the *gastrocnemius* and *soleus* muscles insert at opposite parts of the *os calcaneum* and lead to an asymmetrical load pattern of the Achilles tendon (WALLENBÖCK, 1995). Hence, the transfer of forces between muscle and tendon leaves much room for manoeuvre or, to be more precise, asymmetrical, dynamic transfer possibilities, which are causally important for the development of Achilles tendon problems.

Traumatology

The two most important forms of Achilles tendon injuries are ruptures and a range of problems known as achillodynia.

Ruptures

Although loads that far exceed the theoretical strength capacity of the Achilles tendon are regularly tolerated, it is understandable that in certain sports with highly dynamic motions, including athletics, pronounced problems of the Achilles tendon can develop and these can even lead to ruptures. With an incidence of 1:10,000/year, the Achilles tendon rupture is one of the most frequent tendon injuries in sport. The incidence of this type of injury rises with increasing age (PETERSON, 2002).

Partial or total ruptures of the Achilles tendon without injuries of the covering skin are called subdermal ruptures. These are classified according to where they occur. These include ruptures at the location of the smallest diameter of the tendon (the so called *loco classico*), which is 3 to 5cm above the onset of the *Tuber Calcanei*, and distal cuts of the tendon that happen with an *osseus* tear fragment from the *calcaneus*. In 90% of all cases the Achilles tendon will rupture at the predilection site, the point of its smallest diameter (ARNDT, 1976). Quite rarely, a rupture is located at the proximal section of the *triceps surae*. This is called "tennis leg" (SCHMIDT, 1981).

In addition to mechanical factors, endogenous and exogenous factors like infections,

Table 2: Pathogenetic factors of achillodynia (according to ACHTEN, 1986)

Systematic Disorders	Impaired Biomechanics	Endocrine Disorders and Metabolic Diseases	Local Nutritional Disorders	External Influences
Rheumatic forms: • PCP • Reiter's syndrome • Bekhterev's disease • Chronic nephritis • Chronic osteomyelitis • Lues • Typhoid • Tuberculosis	• Foot deformity after trauma (flat foot) • False posture of the foot (pes plano valgus) • Fony spur (Haglund Exostosis, Calcaneus spur) • Athrosis deformans • Overuse due to injuries in the contra-lateral lower extremities	• Diabetes mellitus • Gout • Hyperpara-thyroidism	• Fokal-toxic inflammations • Improper injections (especially of corticoids) • Circulatory disorders • Varicosis endangitis obliterans	• Wrong footwear (too little cushioning effect, too flat heel) • Inappropriate surface conditions (asphalt jogging, indoor tennis) • Inappropriate organisation of training (no stretching exercises) • Unfavourable running style

metabolic diseases, rheumatic problems, arteriosclerosis, genetic predisposition and cortisone injections can contribute to Achilles tendon injuries (ARNDT, 1976; JÒZSA, 1997; STEINBRÜCK, 2000). In sport, however, Achilles tendon ruptures are mainly the result of mechanical causes, often due to an unfavourable balance of power in the muscle/tendon cross-section of 120-150:1 and a maximum load capacity of the tendon of 9,000 to 11,000N/cm^2 (STEINBRÜCK, 2000). In this context, according to ARNER & LINDHOLM (1959) and STEINBRÜCK (2000), the following operational sequences with eccentric muscle contractions are of importance:

- Take-off from extended knee joint with maximally contracted calf muscles (sprints, accelerations),
- Unexpected dorsal extension in the upper ankle joint with a reflex contraction of the calf muscles (a forward fall, i.e. slipping on a staircase with a sudden drop of the heel),
- Dorsal extension in the upper ankle joint at landing in plantar flexion (jump landing, especially from high platforms).

Achillodynia

More than one hundred years ago, ALBERT (1893) used the term achillodynia to describe problems at the base of the Achilles tendon caused by a specific inflammation of the *bursa calcaneare*. Achillodynia is marked by pain about 2-6cm above the calcaneal base at pressure and at rest or strain (ULREICH, 2002). The initial pain and, as a clinical guiding symptom, a hampered rolling function of the foot are typical. Achillodynia is a common disease pattern, especially in serious and high-performance sport, and it often persists or recurs (THIEL, 1982; CHEN, 1992). Achillodynia does not allow a continuation of running loads and hence forms one of the most common causes for breaking off a career in athletics (LOHRER, 1996). As achillodynia is closely associated with both running and football, it also affects many leisure-time and fitness participants. In the industrialised countries the incidence of achillodynia has quadrupled in the last 20 years.

Table 2 gives an overview of the range of possible causes of achillodynia that have been identified.

Serious athletes first experience achillodynia at an average age of 23.5 years, mass sports athletes at 39.2 years. Table 3 shows that among those with the condition there are

Table 3: Epidemiology of achilles tendon pain syndrome. Runners in sports with forefoot loads (sprints, jumps) and heel-runners (long distances) are affected in similar incidence (LOHRER, 1996)

Sprints and Jumps	18 (39%)	
Middle & Long Distance	24 (52%)	
Combined Events	4 (9%)	
	Achillodynia	Bursitis Subachillae
Normal foot	6(23%)	1 (12%)
Elevated instep	11(42%)	5 (62%)
Fallen arches	9 (34%)	2 (25%)

both heel-runners and ball of the foot- or fore-foot-runners (track and field athletes from the sprinting/jumping events and the running events). Runners with an elevated instep are also at risk but this is less often the case for runners with fallen arches.

Pain associated with achillodynia can manifest in the Achilles tendon itself and nearby areas including the muscle origin, the insertion, the bursas and the gliding tissue of the tendon. The following syndromes can be distinguished, depending on the location and their clinical symptoms (see Figure 1):

- in the area of the muscle origin,
- within the tendon itself,
- in the area of insertion,
- within the bursa,
- within the *circumfluent paratenon*.

The clinical differentiation between the various forms of achillodynia is very difficult (ROMPE & STEINBRÜCK, 1982; PETERSON & RENSTRÖM, 2002). Moreover, when numerous areas are affected, it can be hard to find out where the problem has taken its origin (SCHÖNBAUER, 1986; JÒSZA, 1997).

ALFREDSON & LORENTZON (2000) point out an additional problem, namely the non-uniform use of terms to describe syndromes. Within the scope of surgical operations and post-operative rehabilitation measures, the

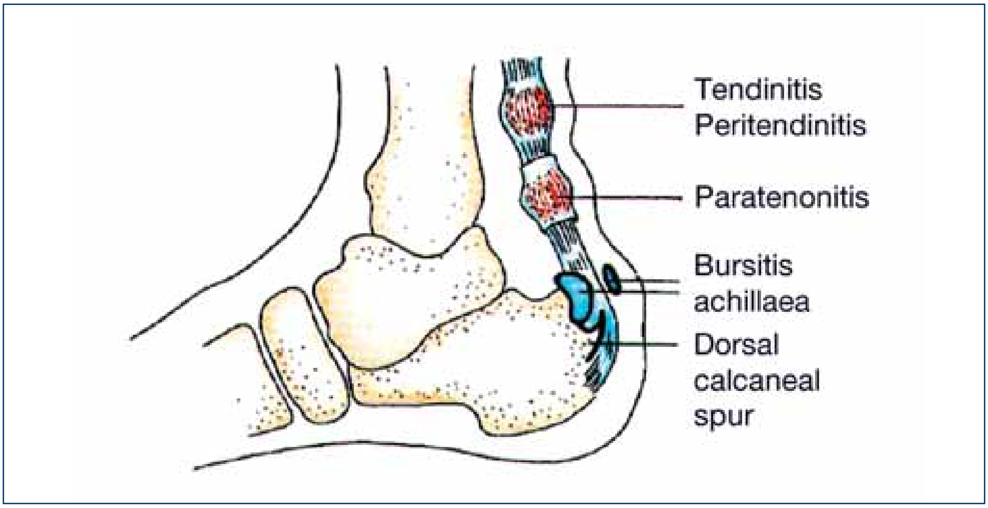

Figure 1: Achillodynia and its most frequent causes (according to GEIGER, 1997)

following terms are used for chronic, painful changes in the Achilles tendon:

- Achillodynia,
- Tendinitis,
- Tendonitis,
- Tendinosis,
- Chronic tendinopathy,
- Partial rupture.

Injury, Overload, and Healing Mechanisms

Achilles tendon injuries, like other muscular-skeletal sports injuries, can be brought on by intrinsic and extrinsic factors, separately or in combination. Intrinsic factors predominate with overuse injuries, in the case of acute traumas, however, extrinsic factors are more commonly involved.

In theory, an overload is a repeated flexing of the tendon (3 – 8% of the initial stretch tension), until a critical value is reached. Tissue damage results if the tension exceeds the upper value (JÒSZA, 1997). By repeated tension the tendon is disrupted both microscopically and macroscopically. In this case, the collagenic fibres glide past each other and a rupture develops between the “crosslinks” (KANNUS et al., 2002), which are located between them. Additionally, a denaturation or inflamation with edema and pain emerges. In this way the various clinical pictures of achillodynia come into being, as well as a first manifestation of a tendon overuse injury (HESS, 1989).

The self-repair capacity of the tissue of the Achilles tendon is limited, especially in the case of regularly repeated loads. The blood supply of the Achilles tendon can deteriorate due to an injury of the micro- or macrovascular structures. Capillary occlusions are frequently found together with tendon damage and they lead to a reduction of metabolic activity and disturbed oxygen transport (JÒSZA, 1997).

Prevention

Prevention of Achilles tendon injuries calls for the athlete, coach and support personal to be

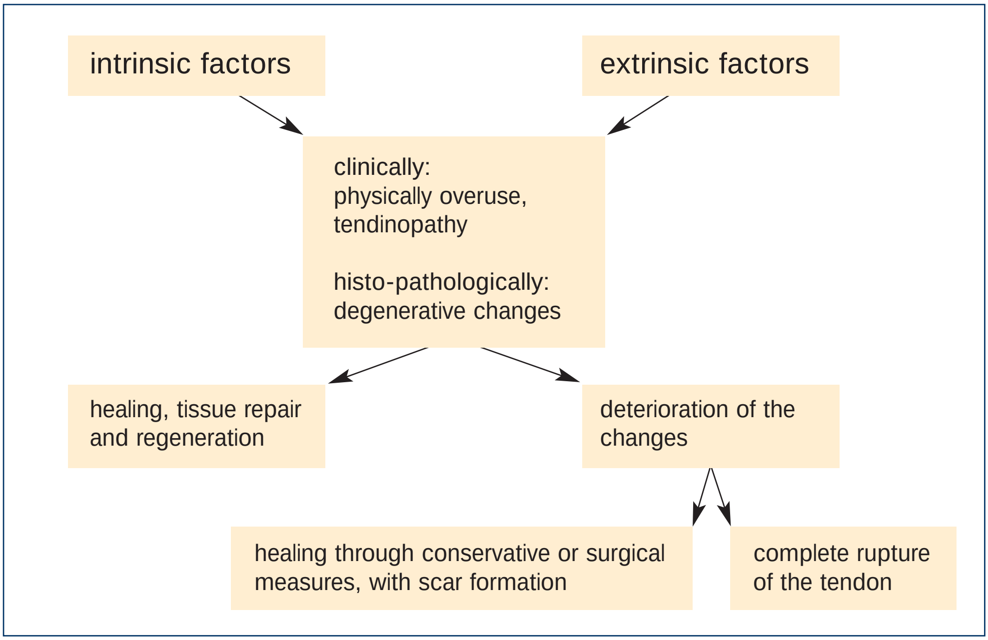

Figure 2: Assumed pathophysiological mechanisms of tendon overuse injuries, which are also considered as factors of a tendon rupture (according to KANNUS et al., 2002)

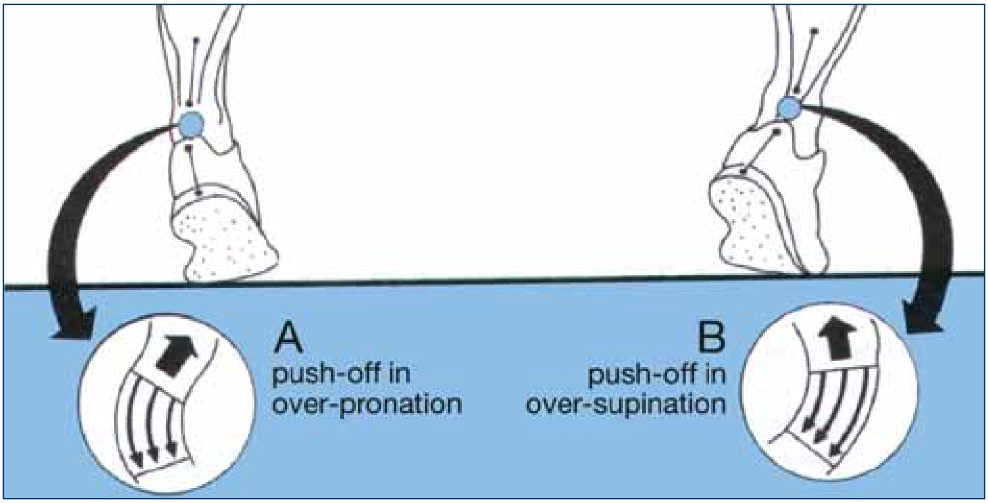

Figure 3: Asymmetrical Achilles tendon strain in A) over-pronation and B) over-supination (right foot) (GEIGER, 1997)

aware of and, if required, proactively treat for the risk factors listed below. In any case, the coach should ensure that a thorough analysis by an orthopedist specialised in sports, is carried out on each athlete beginning training focused on high performance sport.

Intrinsic factors

Intrinsic factors, in particular anatomical peculiarities of the athlete, such as bad posture, are assumed to have consequences on the load effect of the Achilles tendon and Achilles tendon injuries. The most important are considered to be malalignments of the axes, exaggerated pronation, stiffness of the *gastrocnemius* and *soleus* muscles, muscular imbalance and age (PETERSON, 2002).

For example, in a *tibial varus* and a forefoot *varus*, pronation is excessively developed. A forefoot *varus* of more than 7° has been found in more than half of runners with Achilles tendon problems. Hence it is assumed that functional hyper-pronation is a common cause of the problems. However, at the moment no biomechanical indication for an increased local stress of the Achilles tendon due to hyper-pronation has been demonstrated (MAYER, 2000; PETERSON, 2002). Figure 3 shows the asymmetrical pull of the tendon as a consequence of over-pronation (*calcaneus valgus*) and over-supination (*calcaneus varus*).

Additional factors include other anatomical predispositions (ligament insufficiency in the ankle joint, static and dynamic foot insufficiency, Haglund exostosis, pelvic obliquity, etc.), differences in leg length, reduced adaptability, overweight, pre-dispositioning diseases, previous injuries, female gender, and local blood flow (due to ischemia, hypoxia, intratendinous hyperthermia) (MÜLLER, 1996; WEINECK, 1997; KANNUS et al., 2002).

Infectious diseases (e.g. angina of the salpingopalatine fold) or incompletely cured bacterial focuses (teeth, pharyngeal tonsils, etc.) can also lead to degenerative changes of the Achilles tendon (WEINECK, 1997).

Extrinsic factors

It is assumed that extrinsic factors have a greater influence on Achilles tendon problems than intrinsic factors. ARNDT (1976) points out that the theoretical maximum power of a muscle cannot normally be achieved by voluntary innervation. This also applies to the loads triggered by proprioceptive reflexes caused by inhibiting mechanisms such as sudden irritations of the tendon (stretching or a blow). However, there are situations imaginable in sport in which such stimuli are simultaneously effective (i.e. in a plyometric jump). In cooperation with gravity, they can exceed the tolerability of the tendon many times over for a short duration and lead to injury.

Excessive strain on the body from bad training (wrong motion pattern, speed of motion, high repetition frequency, high intensity, quick progression or increase of training loads, hilly terrain, faulty technique, excessive fatigue) is also known to contribute to overuse problems (LOHRER, 1996; KANNUS et al., 2002). In particular, high training volume and excessive load intensity are seen as problem causes by many authors (CLEMENT et al., 1981; MACERA, 1989; VAN MECHELEN, 1992; BRILL & MACERA, 1995; MAYER, 1999). Runners who have a training volume of more than 32 km/wk are considered particularly at risk. However, no correlation between running speed and injury incidence has been found (MARCERA, 1989).

Additional factors in overuse problems are suboptimal environmental conditions (darkness, heat, coldness, humidity, wind, ground surface), as well as bad equipment (footwear, sportswear) (PETERSON, 2000; KANNUS et al., 2002).

Training methodological factors

As training has been identified as a source of problems that can contribute to Achilles tendon injuries, it is necessary for coaches to look, from the point of view of prevention, more closely at the training methodology they employ. Specific examples for coaches to consider include:

1. With inadequate warm-up the nutritional situation of the Achilles tendon cannot completely adapt to high load intensities and volumes. This can lead to metabolic disorders and, over time, degenerative changes of the Achilles tendon (SAGERER & FREIWALD, 1994).

2. Persistent load volumes, especially on the ball of the foot, as is the case in a series of jumps, often produce avoidable consequential damages in the area of the Achilles tendon. The excessive and one-sided use of one training means can also lead to problems, even on appropriate terrain and at adequate intensity (MÜLLER, 1996; WEINECK, 1997; PETERSON, 2002).

3. In extensive and highly intensive jump loads (i.e. in a training unit of competitive high or long jumps), the coach has to consider the affective and emotional state of the athlete. The load peaks that come into effect in such situations can easily lead to problems.

4. The lack of a compensatory training, such as insufficient stretching of the calves or inadequate strengthening of the antagonist muscles, can lead to imbalances, which in the long run lead to local stress and overuse in the tendons (MÜLLER, 1996; WEINECK, 1997; PETERSON, 2002; KANNUS et al., 2002).

5. Lack of knowledge about correct technique in strength training, the sprints (where there can be more than 8,000N in a support phase of the stride) or jumping exercises (where there can be more than 11,000N in a high jump take-off) can aggravate pre-existing defects of the biological structures (JANSHEN, 1996).

6. Careful attention should be paid to good axial alignment of the knees and feet in jumping exercises and sprinting. Observations and evaluations can be complicated by potential (possibly not even detected) malalignments of the feet, knees or hip. Supervision from the rear perspective is particularly advisable, as incorrect lateral deviations of the *os calcaneum* are more obvious. The evaluation of loads (i.e. in take-offs) should not only be seen from the perspective of muscle contractions, but also from the perspective of passive loads, e.g. when planting the foot. “Causes for complaints can hence not only be

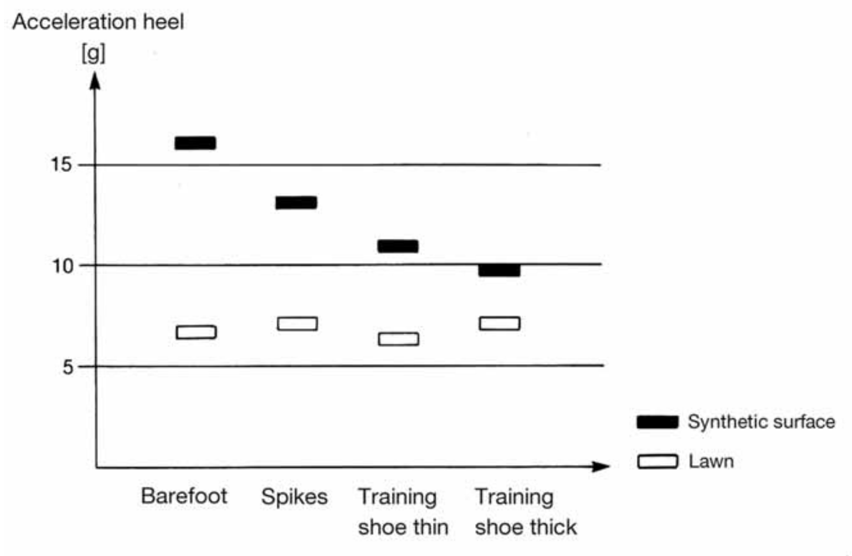

Figure 4: Passive acceleration forces in running (heel running) with various footwear on a synthetic track or grass (NIGG, 1980).

found in stretchings of tendons, but also in shear forces, compressive, bending and torsion loads." (MÜLLER, 1986).

7. A negative effect on the load tolerance of the Achilles tendon is caused by bad footwear (worn out or worn-down soles of the shoes), lack of an elevated heel and over-firm, inelastic soles. In wintry conditions, it is necessary to wear insulating clothes (thick socks would be helpful) to prevent a drop of temperature in the area of the Achilles tendon. Otherwise there is an increased liability for injuries. (SCHEIBE, 1973; BRENKE et al., 1979; SEGESSER et al., 1980; HUDLER, 1983; WEINECK, 1997).

There is a particularly important set of problems that has to do with where training takes place. Running and jumping exercises carried out on a surface that is too hard, too soft or too slippery can cause modifications to the technique or the motion in general. These situations create unusual loads and can bring on Achilles tendon problems. Two common examples are:

1. Athletes who train often on synthetic tracks, are exposed to a special stress caused by vibrations in foot during the support phase of the stride. Due to the high elasticity of the synthetic surface, vibrations in the muscles transfer to the neighbouring tissues with elasticity differences (muscle to tendon transition). These then exert a high mechanical stimulus on the tendons, in what is known as the tartan syndrome (PROKOP, 1972).

2. When there is an abrupt change of training terrain, as is the case in the transition from outdoor to indoor season or vice versa, or a the case of a change from a cinder to synthetic track, there are completely different strains, which may lead to substantially higher loads in the achilles tendon area, and hence the possibility of overuse (MAIER, 1995; WEINECK, 1997; MAYER, 2002). Figure 4 shows the differences in forces experienced while running on a synthetic surface and on grass.

Sport medical factors

Coaches and athletes must also be aware of basic sport medicine and hygiene factors than can impact the Achilles tendons and then adjust their activities accordingly. For example, it has been found that there often is a lack of physio-prophylaxis to improve the blood flow after extreme loads and or over-cooling in training (i.e. timed-runs in winter etc.). This can lead to a reduction of the metabolism in the Achilles tendon and hence to reduced load processing. Some running to warm down and some warmth application or the like after training would, however, provide an improved recovery and an optimal restitution (SCHEIBE, 1973; BRENKE et al., 1979; SEGESSER et al., 1980; HUDLER, 1983; WEINECK, 1997).

It is also known that athletes and coaches frequently ignore the beginning problems or microtraumas in the area of the Achilles tendon. In most cases, highly motivated athletes will practice into the pain and thereby aggravate minor problems. Early action normally prevents degenerative changes caused by such problems, and can hence avoid a persistent achillodynia (SCHEIBE, 1973; BRENKE et al., 1979; SEGESSER et al., 1980; HUDLER, 1983; WEINECK, 1997).

Please send all correspondence to:
skroesche@gmx.de

REFERENCES

ACHTEN, B. (1986). Beantwortung der Leserfrage: Achillodynie. Praktische Sport- Traumatologie und Sportmedizin, 3, 25.

ALBERT, E. (1893): Achillodynie. Wiener Med Presse, 34, 42-43.

ALFREDSON, H. & LORENTZON, R. (2000). Chronic Achilles tendinosis: recommendations for treatment and prevention. Sports Medicine, Auckland (N.Z.), 29 (2), 35-146.

ARNDT, A. N. (1997). Entstehung und Auswirkungen asymmetrischer Belastung der menschlichen Achillessehne unter besonderer Berücksichtigung ihrer Morphologie. Köln: Sport & Buch Strauß.

ARNDT, K. -H. (1976). Achillessehnenruptur und Sport. Leipzig: Sportmedizinische Schriftenreihe Heft 10, Johann Ambrosius Barth.

ARNER, O. & LINDHOLM, A. (1959). Subcutanous rupture of Achilles tendon. Acta Chir Scand 239 (Suppl.) 1.

BURDETT, R.G. (1982). Forces predicted at the ankle during running. Medicine and Science in Sports and Exercise, 14 (4); 308-316.

BRILL, P. & MACERA, C. (1995). The influence of running patterns on running injuries. Sports Medicine, 20, 365-368.

BRENKE, H.; JUNGMICHEL, L.; DIETRICH, L. & WEBER, J. (1979). Zur Prophylaxe und Rehabilitation der Achillodynie aus sportmethodischer Sicht. Medizin und Sport, 11, 337-341.

LJUNGQVIST, R. (1968). Subcutaneous Partial Rupture of the Achilles Tendon. Acta Orthopaedica Scandinavica, Suppl. 113.

CLEMENT, D.; TAUNTON, J.; SMART, G. & McNICOL, K. (1981). A survey of overuse running injuries. The Physician and Sportsmedicine, 9, 47-58.

CHEN, S.C. (1992). Sprunggelenksverletzungen. In: Sportverletzungen, Hrsg.: Helal, B.; King, J. & Grange, W., Thieme 1992.

EHRICHT, H.G. & PASSOW, G. (1972). Achillodynie – Achillessehnenruptur. Genese, Klinik, Therapie, Prophylaxe und Metaphylaxe. Medizin und Sport, 12, 333-340.

EHRSAM, R. (1974). Die Achillodynie. Therapeutische Umschau, 31, 266-270.

FUKASHIRO, S.; KOMI, P.V.; JÄRVINEN, M. & MIYASHITA, M. (1995). In Vivo Achilles Tendon Loading During Jumping in Humans. European Journal of Applied Physiology, 71, 453-458.

FRANKE, J.S. (1990). Biomechanische experimentelle Untersuchung zum Rissverhalten der menschlichen Achillessehne, med. Dissertation, TU München.

GEIGER, L. (1997). Überlastungsschäden im Sport, BLV-Sportwissen, München, p.156.

GREGOR, R.J.; ROY, R.R; WHITING, W.C.; LOVELY, R.G.; HODGSON, J.A. & EDGERTON, V.R. (1988). Mechanical Output of the Cat Soleus During Treadmill Locomotion: In Vivo vs In Situ Characteristics. Journal of Biomechanics, 21 (9), 721-732.

GROSJEAN, B. & DEJUNG, B. (1990). Achillodynie – ein unlösbares Problem? Schweiz. Ztschr. Sportmed, 38, 17-24.

HEGER, H. (1966). Verletzung und Belastung der Achillessehne des Geräteturners. Praxis der Leibesübungen 2, 27-29.

HESS, G.; CAPIELLO W., POOLE R., HUNTER S. (1989): Prevention and Treatment of overuse tendon injuries. Sports Med 8:371-384.

HERZOG, W. & LOITZ, B. (1994). Biomaterials: Tendon. In: Nigg, B.M., Herzog, W. (Hrsg.): Biomechanics of the musculo-Skeletal System,133-153. Cichester, England: John Wiley and Sons.

HUDLER, J., SLAVIK, Z. & MATEJOVSKY, Z. (1983). Beschädigung der Achillessehne infolge der lokalen Applikation der Kortikoide. In: Sportverletzungen und Sportschäden, Hrsg: Chapchal P., Stuttgart-New York: Thieme.

JANSHEN, L. (1996): Muskuläre Kontrolle bei Landungen im Kunstturnen. Eine experimentelle Untersuchung zum Innervationsverhalten der Flexoren und Extensoren der unteren Extremität. Diplomarbeit. Köln: Deutsche Sporthochschule.

JUNGMICHEL, D. & NAWROTH, U. (1989). Konservative und Operative Therapie der Achillodynie. Medizin und Sport, 29(7), 236-240.

JÒZSA, L.; KVIS, T. M.; BALINT, B. et al. (1989). The Role of Recreational Sport Activity in Achilles Tendon Rupture: A Clinical, Pathoanatomical and Sociological Study of 292 cases. American Journal of Sports Medicine, 17, 338-343.

JÒZSA, L. & KANNUS, P. (1997): Histopathological findings in spontaneous tendon ruptures. Scandinavian Journal of Medicine & Science in Sports, 7, 113-118.

JÒZSA, L. & KANNUS, P. (1997). Human Tendons: Anatomy, Physiology and Pathology. Champaign Il: Human Kinetics.

KAPANDJI, I.A. (1992). Funktionelle Anatomie der Gelenke. Band 2: Untere Extremität. Stuttgart: Ferdinand Enke.

KANNUS, P.; PAAVOLA, M.; PAAKKALA, T.; PARKKARI, J.; JÄRVINEN, T. & JÄRVINEN, M. (2002). Pathophysiologie des Sehnenüberlastungsschadens. Der Radiologe, 42(10), 766-770.

KOMI, P.V. (1990). Relevance of In Vivo Force Measurements to Human Biomechanics. Journal of Biomechanics, 23 (Suppl. 1), 23-34.

LOHRER, H. (1992). Die Achillessehne im Sport – ungeliebtes Krankheitsbild Achillodynie. TW Sport-Medizin, 4, 377-381.

LOHRER, H. (1996). Sportorthopädie und Sporttraumatologie,12 (1) 36-42.

LUNDBERG, A.; GOLDIE, I.; KALIN, B. & SELVIK, G. (1989). Kinematics of the Ankle/Foot Complex: Plantarflexion and Dorsiflexion. Foot and Ankle, 9 (4), 194-200.

MACERA, C.; PATE, R.; POWEL, K.; JACKSON, K. & KENDRICK, J. (1989). Predicting lower extremity injuries among habitual runners. Archives of Internal Medicine, 149, 2565-2568.

MAIER, T. (1995). Die Achillodynie als leistungslimitierender Faktor im Spitzensport. Schweizerische Zeitschrift für Medizin und Traumatologie, 43 (2), 49- 54.

MAYER, F. & DICKHUT H.-H. (2002). Chronische Achillessehnenbeschwerden im Sport. Deutsche Zeitschrift für Sportmedizin, 53, 256-257.

MAYER ,F.; GRAU, S.; MAIWALD, C.; PLOOG, N.; BÄUERL, W.; BECK, M.; BAUR, H. & MÜLLER, O. (1999). Current changes in running injuries. International Journal of Sports Medicine, 20, 103.

MAYER, F.; GRAU, S.; BÄURL, M.; KRAUSS, MAIWALD, C & BAUR, H. (2000). Achillessehnenbeschwerden im Laufsport – eine aktuelle Übersicht. Deutsche Zeitschrift für Sportmedizin, 51, 61-167.

MÜLLER, G.; STACOFF, A. & STÜSSI, E. (1996). Mögliche Ursachen von Problemen im Bereich der Achillessehne, Schweizerische Zeitschrift für Medizin und Traumatologie, 44 (1), 27-31.

PETERSON, L. & RENSTRÖM, P. (2002). Verletzungen im Sport. Köln: Deutscher Ärzte-Verlag.

PROKOP, L. & HABERL, R. (1972). Die Auswirkungen von Kunststoffbahnen auf den Bewegungsapparat. Öst. Journal Sportmed. 2, 3.

ROMPE, G. & STEINBRÜCK, K. (1982). Konservative Therapie von Sehnenerkrankungen, in: Sportliche Belastungsfähigkeit des Haltungs- und Bewegungsapparates, Hrsg.: Groher, W. & Noack, W., Thieme.

SAGERER C., FREIWALD J. (1994). Aufwärmen Leichtathletik: Lauf und Sprung. Reinbek bei Hamburg: Rowohlt Taschenbuch Verlag GmbH.

SEGESSER, B.; NIGG, B.M. & MORELL, F. (1980). Achillodynie und tibiale Insertionstendinosen. Medizin und Sport 3, 79-83.

SEGESSER, B. (1974). Tibiale Schmerzzustände und Achillessehnenentzündungen als Folge statischer Störung. Therap. Umschau 31, 256-265.

SCHEIBE, A. (1973). Achillessehnenschwäche. Theorie und Praxis der Körperkultur 3, 259-262.

SCHMIDT, A. (1981). Die Achillessehnenverletzung, Dissertation, Universität zu Köln.

SCOTT, S.H. & WINTER, D.A. (1990). Internal Forces at Chronic Running Injury Sites. Medicine and Science in Sports and Exercise, 22 (3); 357-369.

SCHÖNBAUER, H.R. (1986). Erkrankungen der Achillessehne. Wiener klinische Wochenzeitschrift 98, 8.

STEINBRÜCK, K. (2000). Achillessehnenruptur im Sport – Epidemiologie, aktuelle Diagnostik, Therapie und Rehabilitation. Deutsche Zeitschrift für Sportmedizin, 51, 154-160.

THIEL, A. & KARPF, M. (1973). Bild und Behandlung der Achillodynie. Sportarzt und Sportmedizin 5, 106-107.

THIEL, A. (1982). Verletzungen in der Leichtathletik. Sportverletzungen in der Praxis, Hrsg.: Jäger M., Keyl W., Wirth C.J., Thieme .

ULREICH N., KAINBERGER F., HUBER W., NEHRER S. (2002). Die Achillessehne im Sport. Der Radiologe, 42 (10), 811-817.

VAN MECHELEN, W. (1992). Running Injuries: A review of the epidemiological literature. Sports Medicine, 14, 320-335.

VERDONCK, A.; WIEK, M. & WILKE, C. (2003). Testverfahren. In: Training in der Therapie. Hrsg: Nellessen, G.; Froböse, I. & Wilke, C. München: Urban & Fischer Verlag.

WALLENBÖCK, E.; LANG, O. & LUGNER, P. (1995). Stress in the Achilles Tendon during a Topple-Over Movement in the Ankle Joint. Journal of Biomechanics, 28 (9), 1091-1101.

WEINECK, J. (1997). Sportanatomie. Balingen: Demeter Verlag im Spitta Verlag GmbH.

WELSH, R. & CLODMAN, J. (1980). Clinical survey of Achilles tendinitis in athletes. Canadian Medical Association Journal, 122, 193-195.