SECONDARY EFFECTS OF KNEE BRACES ON THE INTRACOMPARTMENTAL PRESSURE IN THE ANTERIOR TIBIAL COMPARTMENT

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In 31 healthy volunteers aged 18 to 33 years we investigated the intracompartmental pressure in the anterior tibial compartment while running on a treadmill with, and without, a functional knee brace. All volunteers performed two test series with a constant running speed of 8 km/h. Prior to running, the pressure was documented in the supine, sitting and standing position as well as during running.

The intracompartmental pressure in the supine position was significantly less without a brace compared to the pressure with a brace. This was also true for the sitting position and the standing position. While running on the treadmill the average pressure was also significantly higher with, than without, a brace.

Clinical relevance : Running with a functional knee brace leads to increased intracompartmental pressure in the anterior tibial compartment and, as a consequence, may lead to a chronic compartment syndrome. Wearing a functional knee brace may cause secondary muscle ischemia and may be one reason for the increased incidence of injuries in athletes.

Keywords : knee-brace ; intracompartmental pressure ; anterior tibial compartment.

Mots-clés : orthèse du genou ; pression intra-compartimentale ; compartiment tibial antérieur.

INTRODUCTION

More than 100 years ago compartment syndrome was described for the first time in the literature by Volkmann (24). In 1881 he published his observations regarding the consequences of bandages which were tightly applied. Jepson (10) documented that these contractures were due to an impairment of the venous reflux and the development of extravasation.

Later it became quite obvious that besides the posttraumatic compartment syndrome a *functionally* induced compartment syndrome exists as well. The *functionally* induced ischemia of the muscles after exercise was described especially for the anterior tibial compartment and can furthermore be differentiated into an acute and a chronic type.

The acute functional compartment syndrome occurs during, or immediately after, very strenuous exercise. It can lead to muscle necrosis which was originally observed among young people after long marches.

The chronic functional compartment syndrome occurs much more often than the acute type. According to Reneman it is bilateral in the majority of cases (18). In recent years this type has received more and more attention, mainly in high-level competitive athletes. It is found especially among competitive walkers and mid-distance runners, as well as in other athletic activities. The chronic type does not lead to muscle necrosis nor to permanent damage. Nevertheless it is a limiting factor for performance in some athletes (11, 12).

In recent years we have seen an increasing number of athletes who suffer from major complaints and edema of the lower leg when wearing knee braces during athletic activities. Therefore, we investigated the consequences arising from external compression by the knee brace on the pressure

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in the anterior tibial compartment, and whether the intracompartmental pressure reaches a level which may result in potential muscle damage.

MATERIAL AND METHODS

Thirty-one healthy male volunteers aged 18 to 33 years (mean : 25.8 years) participated in this study. Criteria for exclusion were posttraumatic conditions of the lower extremities, pain in the lower leg during exercise as well as any kind of medical therapy. Different levels of individual physical activity were represented as the volunteers were recruited from sports students (n = 15) and individuals with leisure activities (n = 11) as well as nonathletes (n = 5).

Method of measuring the tissue pressure : The pressure documentation was performed with an MCDM-1 device (Mobile Compartment Pressure Measurement System, Mammendorfer Institut, München, Germany). The sensor (fig. 1) of this system operates with a piezoelectric mechanism. A change of pressure is converted directly into a digital signal received by the measuring device and recorded in mmHg. The measuring frequency of the system is 1000 Hz. The entry signal is attenuated by means of a low pass with a calibrated frequency of 50 Hz (- 3 dB). The advantage of this special device is that no external measuring instrument has to be fixed to the lower leg. After careful desinfection of the site of entry, local anesthesia using 1.5 ml of a local anesthetic was performed. Then the measuring probe of the MCDM-1 was implanted halfway between the lateral joint line of the knee and the lateral malleolus using a venous catheter with ultrasonic guidance. The correct position of the probe was checked by reproducing a reversible increase in the pressure during active muscle contraction and during application of external pressure. Continuous pressure registration was performed by an additional xy-recorder (L 6012-1, Linseis, 8672 Selb, Germany).

Test procedure : All volunteers completed two tests on the treadmill, each time with a constant speed of 8 km/h and a gradient of 0% (Woodway ES1V, 35-40 shore). All volunteers wore regular running shoes and performed two tests : one run with knee brace (Lenox-Hill standard derotation brace, Smith & Nephew Don Joy Incorp., Carlsbad, CA, USA) (fig. 2) and one run without brace. On the basis of a randomized list the volunteers were assigned to the different running conditions. Each run lasted 7 minutes.

The intracompartmental pressure was continuously measured and recorded from the moment of insertion of the probe into the compartment of the anterior tibial muscle until the end of the test.

Fig. 1. — Sensor of MCDM-I device in comparison to a coin.

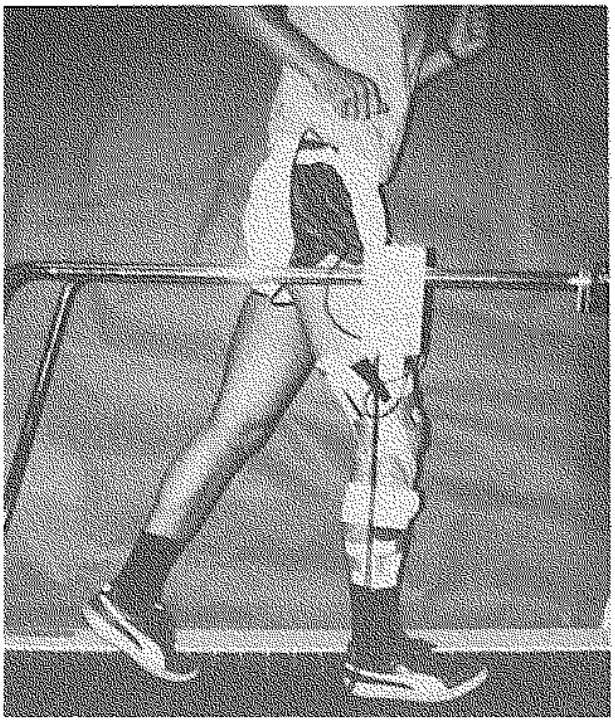

Fig. 2. — Set-up with volunteer on the treadmill.

Prior to the run the intracompartmental pressure was documented during rest in the supine, sitting and standing positions. Then we registered the average pressure between the third and the seventh minute of running as well as the minimal and maximal pressure during running with and without a brace.

The data were analyzed with the SPSS statistical package. The statistical calculations between the differences of the means were done with Student's t test. Differences were considered to be significant if the p-value was less than 0.05.

RESULTS

The intracompartmental pressure during rest prior to running in the supine position was 4.6 mm Hg (± 2.1 mm Hg) without brace and 19.6 mm Hg (± 8.3 mm Hg) with brace. In the sitting position it increased to 6.7 mm Hg (± 2.7 mm Hg) without brace and 26.3 mm Hg (± 5.7 mm Hg) with brace. In the standing position there was a further pressure increase up to 15.2 mm Hg (± 4.7 mm Hg) without brace and 38.7 mm Hg (± 11.5 mm Hg) with brace (fig. 3). Statistical evaluation showed that the intracompartmental pressure was significantly higher ($p < 0.05$) with a brace for all three positions (supine, sitting, standing).

At a running speed of 8 km/h the mean pressure in the anterior tibial compartment was 49.1 mm Hg (± 8.2 mm Hg) without brace. During the run with a knee brace the results showed a highly significant increase in the pressure up to 95.6 mm Hg (± 13.5 mm Hg) (fig. 4). These differences were also statistically significant ($p < 0.05$). The increase was more than 80% in comparison to the test without brace. Six volunteers even achieved a mean pressure of more than 100 mm Hg. Four of them noticed a dragging pain in the ventral lower leg, but they were still able to finish the test, and none of the volunteers had to interrupt the test before complication.

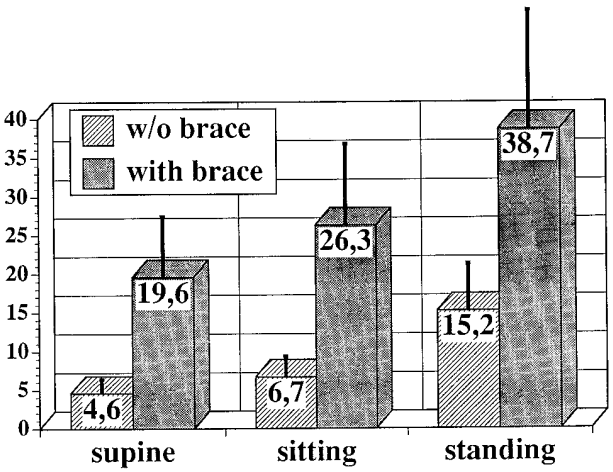

Fig. 3. — Intracompartmental pressure in the anterior tibial compartment in different body positions with and without a brace.

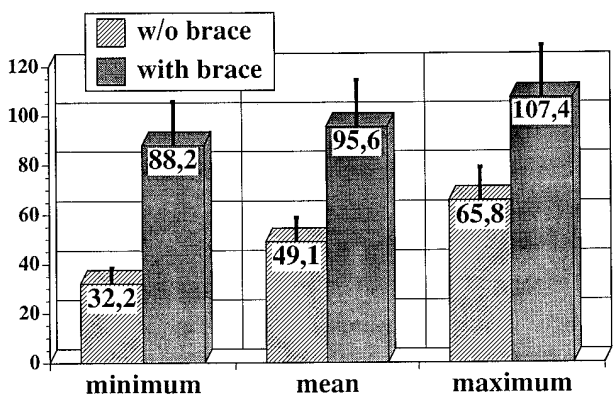

Fig. 4. — Intracompartmental pressure in the anterior tibial compartment during the run with and without a brace.

DISCUSSION

For more than 100 years several authors have described the risk of a compartment syndrome caused by circular dressings (6, 7, 14). Only recently Mars (13) demonstrated that the pressure from an external dressing continues into the compartment in a 1:1 ratio. An average pressure increase of 23 mm Hg could be produced by an elastic bandage only (13). These studies, however, were performed during rest and not during exercise.

We already found a significant pressure increase during static conditions when applying the knee brace. The dynamic measurements during running with and without a knee brace revealed that the mean pressure further increases and can reach more than 100 mm Hg in the anterior tibial com-

partment. Among 4 healthy volunteers this high pressure level led to the typical pain in the area of the anterior tibial compartment, which is the first clinical symptom of a functional compartment syndrome.

To our knowledge there is only one comparable study in the literature. This study was performed by Styf *et al.* (21) who described similar results. After applying a knee brace they demonstrated a pressure higher than 40 mm Hg during rest in the standing position in 9 of the 18 volunteers. In contrast to our study Styf *et al.* tested three different braces. However, they did not find any significant differences between the different braces. Therefore, our results may be extrapolated to other braces, too.

Because of these potential disadvantages the question arises : what are the indications for knee braces ?

In general knee braces can be divided into three different categories (prophylactic, functional, rehabilitative).

The prophylactic brace should protect a healthy knee from severe overloading. There are several studies regarding the effects of these braces. Some authors emphasize the prophylactic effects (1, 9, 19, 20) while others could not prove these protective effects (3, 16, 23). Other authors even demonstrated an increased risk injuries (8, 22). Grace *et al.* (8) examined 580 football players, half of them wearing a prophylactic brace. Their analysis did not reveal any protective effect for the knee joint but a significant increase in injuries involving the ankle joint and the foot. In a retrospective study on more than 4000 football players, Teitz *et al.* (22) stressed the fact that, independent of the brace model, a significant increase in knee injuries, as well as those of the fibula and the ankle, occurred. Furthermore, Osterning and Robertson (15) demonstrated significant changes in the EMG signals of the muscles during treadmill exercise while wearing a brace.

The purpose of functional braces is to stabilize the ligamentous unstable knee joint. According to studies with antero-medial instabilities carried out by Beck, the application of a brace reduced the anterior drawer sign at low sheer forces. With increasing forces, however, the stabilizing effect of a knee brace decreases remarkably (4, 25). Recent biomechanical cadaver studies demonstrate that despite the application of a brace or a tape, the translation and rotation movements of the knee can be limited only during impact of minor forces (2). During a treadmill test with a brace Devita could not discover any significant difference in the force impulse on the knee in comparison to the results without a brace (5). Because the exact position of the brace is a necessary condition for its stabilizing function, interference with the joint mechanics already occurs during minor deviations from the ideal position (17).

The situation of the rehabilitative knee braces looks different. Their function is either to immobilize the knee in a specific joint position or to control the range of motion to a given extent. Results after cruciate ligament replacement show a better outcome of postoperative treatment with a brace, in comparison to cast immobilization. The advantage of this early functional postoperative treatment is the lower degree of muscle atrophy and the improvement in the metabolism of the cartilage.

In the current discussion the socio-economic factors of a brace and its cost effectiveness must be considered.

One possible conclusion from the present studies is that prophylactic as well as functional braces are likely to increase the risk of lower extremity injuries due to the increased intracompartmental pressure. The fatigue of the lower leg caused by ischemia could be a possible cause for an increased incidence of injuries while wearing prophylactic or functional braces. Therefore the benefit of wearing these braces must be questioned in the future.

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SAMENVATTING

J. JEROSCH, W. H. M. CASTRO, I. HOFFSTETTER, R. REER. Sekundaire effecten van knieorthesen op de intrakompartimentale druk in het anteriore tibiale kompartiment.

Bij 31 gezonde vrijwilligers (leeftijd : 18-33 jaar) werd de intrakompartimentale druk in het anteriore tibiale kompartiment gedurende het rennen op een loopband, met en zonder een funktionele knieorthese, gemeten. Alle vrijwilligers werden tweemaal getest met een konstante loopsnelheid van 8 km/u. De druk werd gemeten zowel vóór het rennen in liggende, zittende en staande positie als ook tijdens het rennen

De intrakompartimentale druk in de liggende houding was significant geringer zonder de orthese dan met de orthese. Hetzelfde werd gevonden voor de zittende en de staande houding. Tijdens het rennen op de loopband was de gemiddelde druk significant hoger met dan zonder de orthese.

Klinische relevantie : de toegenomen intrakompartimentale druk in het anterior tibiale kompartiment tijdens het rennen met een funktionele knieorthese kan tot een chronisch kompartiment syndroom leiden. De sekundaire spierischemie kan een reden voor de toegenomen incidentie van letsels tijdens het dragen van een funktionele knieorthese bij atleten zijn.

RÉSUMÉ

J. JEROSCH, W. H. M. CASTRO, I. HOFFSTETTER, R. REER. Effets secondaires des orthèses du genou sur la pression intracompartimentale dans le compartiment tibial antérieur.

La pression intracompartimentale dans la loge tibiale antérieure fut mesurée chez 31 volontaires (âgés de 18 à 33 ans), pendant la course sur un tapis de marche, avec et sans orthèse du genou.
Toutes les mesures furent répétées avec une vitesse de course constante de 8 km/h. La pression fut mesurée aussi bien avant la course en position couchée, assise et debout, que pendant la course.

La pression intracompatimentale en position couchée était nettement moins importante sans orthèse qu'avec orthèse ; mêmes constatations en position assise et en position debout. Pendant la course, la pression moyenne était notablement plus élevée avec orthèse que sans orthèse.
Signification clinique : l'augmentation de la pression intracompartimentale dans la loge tibiale antérieure pendant la course, avec une orthèse fonctionnelle, peut évoluer vers un syndrome de loges. L'ischémie musculaire secondaire peut également être à l'origine de lésions chez les athlètes qui portent une orthèse fonctionnelle.