Straight-leg raising in 'short hamstrings'. An experimental study of muscle elasticy and defense reactions.
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The central question asked in this thesis is whether an Experimental Straight-Leg Raising test (E.S.L.R.) can contribute to the solution of a diagnostical problem frequently encountered in rehabilitation medicine. It concerns the determination of the cause of the movement restriction in patients who are unable to bend forward normally from the standing position while holding the knees in extension. For this purpose a clinical test is used aimed to diagnose, on the one hand, the compression of a lumbosacral nerve root and, on the other hand, a poor elasticity of the hamstrings, i.e. short hamstrings. Dependent on the aim, the test is called Lasègue's test or passive muscle stretch test, respectively. Since the execution of both tests does not differ the neutral term Clinical Straight-Leg Raising (C.S.L.R.) has been chosen to denote the test movement.

The current diagnostical approach in patients with the above mentioned movement restriction is described in Chapter 1. It is argued that practical experience supported by case reports casts doubt on the ability of the test to differentiate between short hamstrings (elastogenic pathology) and other causes (non-elastogenic pathology).

The possible reasons for the problems encountered in C.S.L.R. are considered in Chapter 2. It is concluded that the information obtained with the test is insufficient to differentiate correctly, particularly because of the lack of information it yields over the activity of the muscles and the use of incorrect variables regarding the elasticity of the relevant muscles.

In order to generate better variables, an analysis is made in Chapter 3 of the extension of the relevant muscles and the forces acting on the leg and the pelvis. For this purpose a simple theoretical model is used, in which the muscles are represented by two springs in series. The model reproduces the variables which have to be measured to determine the extensibility and the elasticity of the springs. Muscle extensibility is defined by the maximum increase in length that a muscle admits with respect to its length in the inactive supine position. Muscle elasticity is defined by the relation between load and the increase in the muscle's length.

Based on the conclusions drawn from the analysis, an Experimental
Straight-Leg Raising set-up was developed which is described in Chapter 4. The set-up makes it possible to determine the extensibility and the activity of the muscles by measuring the excursion of the leg, the change in the hip angle and the back angle, the electrical activity in the mm. erector spinae, gluteus maximus and semimembranosus, the flattening of the back and the applied lift force. Since the weight and the length of the leg are measured too, the moment necessary to overcome the elastic retraction forces in the muscles can also be determined. Because it is important in this study to measure the hip angle correctly, special attention has been paid to the problems encountered in measuring the hip angle while discussing the measuring procedure.

The general findings and the reproducibility of the measurements are discussed and illustrated in Chapter 5. Since reference values are not available in the literature, measurements were performed on volunteers. For this purpose three groups of 8 students were selected according to their flexibility: a flexible group (F), a medium group (M) and a stiff group (S). Group S is used as a control group, because like the patients, these subjects are not able to touch the ground while bending forward with the knees extended. A short history and a superficial physical examination revealed no other abnormalities.

The results of the measurements in the volunteers are presented in Chapter 6. The excursion of the leg and the extensibility of the hamstrings measured in the subjects of group S turned out to be the smallest. One conclusion is therefore that the clinical criteria for a small extensibility of the hamstrings, i.e. not being able to touch the ground while bending forward with the knees extended and a maximum angle between the straight leg and the horizontal plane of less than 80° in C.S.L.R., are generally correct. The results, however, also showed that in subjects with the same leg excursion, a considerable difference in extensibility of the hamstrings may be present as a result of differences in extensibility of the back muscles. In contrast to the findings in the hamstrings, the extensibility of the back muscles, measured until the leg attained the vertical position, did not differ much between the groups, although it was largest in the subjects of the medium group. It appears that a small extensibility of the hamstrings sometimes is compensated by a large extensibility of the back muscles.

The stiffness of the muscles varied considerably between the sub-
jects within each group, but not systematically between the groups. This means that the movement restriction present in the subjects of group S is not caused by a poor elasticity of the hamstrings. It is therefore concluded that "short" hamstrings are as stiff as "long" hamstrings. Not the elasticity but the differences in extensibility explain the considerable differences between the groups with respect to the maximum value of the moment exerted by the muscles, which is lowest in group S. A plausible explanation for the small extensibility of the hamstrings is a low stretch tolerance of these muscles. The cause of such a phenomenon is not known, but it may be attributed to the nociception in the connective tissue, thus the epi- and perimysium and/or the fascial sheat. This also would explain the problems which are often encountered in differentiating between an intrinsic small extensibility of the hamstrings and other causes for the movement restriction. In the latter case there is also a low stretch tolerance, be it in other structures.

As concerns the EMG activity of the muscles while counteracting the stretching (defense reactions), it was shown that it is largest in the hamstrings of the subjects from group M and S. Generally, the activity does not commence with the first feeling of muscle tension, but with the feeling of pain at an angle between the leg and the horizontal plane varying between 40°-90°. Usually only one of the muscle groups in series is active, most often the m. semimembranosus, sometimes with accompanying activity in the m. gluteus maximus. The activity increases gradually as the leg rises. Activity in both the hamstrings and the back muscles was established in only two subjects of group S, in neither simultaneously. Since the defense activity recorded in the muscles of the volunteers in this study is considered a physiological phenomenon, it is called normal defense reaction. The flattening of the back is shown to depend on the stiffness of the muscles relative to each other. Because the tension in the hamstrings increases immediately after the start of the leg raise, it is concluded that there is no real slack in these muscles.

The results of the measurements in the patients are presented in Chapter 7. Thirty subjects without neurological symptoms, all unable to bend forward normally, were selected by the physicians working at the Rehabilitation Department of the University Hospital in Groningen. They
received the diagnosis Clinical Short Hamstrings (CSH) when the movement restriction was attributed by the referring physician to an elastogenic cause. The diagnosis No Clinical Short Hamstrings (NCSH) occurred when a non-elastogenic cause was assumed. The selection procedure was continued until each group consisted of 15 patients. Because the excursion of the leg in some of the patients was restricted at both sides, the experiments were performed on 40 legs in total: 22 legs with the label CSH and 18 legs with the label NCSH.

Based on the type of the recorded muscle activity, two categories of legs could be distinguished. One category of 25 legs showed EMG activity similar to that recorded in the control group (group S), i.e. Normal Defense Reactions (NDR). Another category of 15 legs showed different EMG activity, called Abnormal Defense Reactions (ADR). ADR are characterized by an earlier start and/or a more rapid increase of the EMG activity compared to that measured in the control group. The excursion of the leg, the extensibility, elasticity and stretch tolerance of the muscles measured in the legs with NDR, either agreed with those established in the control group or were larger. In the legs with ADR, however, the excursion of the leg and the extensibility and stretch tolerance of the muscles were much smaller, but the stiffness of the muscles was normal until ADR appeared. Abnormal EMG activity was most often present simultaneously in both of the muscle groups in series (9x), but also in only one muscle group, either the m. semimembranosus with or without activity in the m. gluteus maximus (3x) or the m. erector spinae (3x).

The findings in the legs with ADR warrant the conclusion that the cause of the movement restriction in these legs differs from that in the legs of the control group and therefore is per definition "non-elastogenic". From that point of view it is concluded, that in many legs (50%) in which the movement restriction clinically had been attributed to short hamstrings, the real cause was in fact an abnormal defense reaction in one or more muscles. On the other hand, in many of the legs (78%) in which a "non-elastogenic" cause was assumed, no abnormal defense reactions could be detected. In these patients the values of all variables were in agreement with those of the control group. Therefore the cause for the movement restriction in these legs apparently is the same as in the control group: probably a low stretch tolerance of the hamstrings.
As for the clinical consequences of the experimental findings, a distinction is made between the diagnostic and the therapeutic consequences. Regarding diagnostics it is concluded that the dichotomy in "elastogenic" and "non-elastogenic" causes for the movement restriction is incorrect since short hamstrings, a genuine elastogenic cause, do not exist. Moreover it is concluded that the muscle stretch test and Lasègue's test in patients without neurological symptoms are not suitable tools for differentiating between a movement restriction due to an intrinsic small extensibility of the hamstrings and that due to abnormal defense reactions. In consequence it is concluded that it is hazardous to base the therapeutic programme on C.S.L.R.

As for the therapeutic approach in "short hamstrings", it is concluded that the usual therapies, based on the concept of muscle shortening as the causal factor, for example those of Kendall et al. (1952) and Janda (1979), are incorrect since a small extensibility of the hamstrings is not caused by poor muscle elasticity, but probably by a low stretch tolerance. Because such a phenomenon may be considered a physiological mechanism, the therapeutic benefit of stretching exercises in patients with "short hamstrings" is questioned. A more important reason to abandon therapeutic stretching of these muscles is the finding that abnormal defense reactions frequently are overlooked.

The general conclusion of this study is that the experimental findings ask for a revision of both the current opinion regarding the etiology of "short hamstrings" and the diagnostic and therapeutic approach in patients with this phenomenon. In analogy this is possibly also true for other "short" muscles. To answer the central question asked in this study, it is concluded that the additional information yielded bij E.S.L.R. is helpful in differentiating between a low stretch tolerance of the hamstrings and other causes for a movement restriction. Finally it is concluded that the findings indicate that the method may be valuable for the differential diagnostics in those other causes and for the study of other problems concerning muscle elasticity.