

A new hamstring test to complement the common clinical examination before return to sport after injury

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Abstract

Purpose The aim was to introduce and evaluate the reliability and validity of an active hamstring flexibility test as a complement to common clinical examination when determining safe return to sport after hamstring injury.

Methods Eleven healthy subjects (28 years) were tested on repeated occasions, and 11 athletes (21 years) with MRI-verified acute hamstring strain were tested when common clinical examination revealed no signs of remaining injury, i.e. there was no differences between the legs in palpation pain, manual strength tests, and passive straight leg raise. Flexibility, i.e. highest range of motion of three consecutive trials, was calculated from electrogoniometer data during active ballistic hip flexions and conventional passive slow hip-flexions in a supine position. A VAS-scale (0–100) was used to estimate experience of insecurity during active tests.

Results No significant test–retest differences were observed. Intra-class correlation coefficients ranged 0.94–0.99 and coefficients of variation 1.52–4.53%. Active flexibility was greater (23%) than passive flexibility. In the athletes, the injured leg showed smaller (8%) active, but not passive, flexibility than the uninjured leg. Average insecurity

estimation was 52 (range 28–98) for the injured and 0 for the uninjured leg, respectively.

Conclusion The new test showed high reliability and construct validity; furthermore, it seems to be sensitive enough to detect differences both in active flexibility and in insecurity after acute hamstring strains at a point in time when the commonly used clinical examination fails to reveal injury signs. Thus, the test could be a complement to the common clinical examination before the final decision to return to sport is made.

Keywords Hamstring strain · Re-injury · Reliability · Return to sport · Validity

Introduction

Clinical experience tells us that it is extremely difficult to decide at which point during rehabilitation the athlete is ready to return to sports after a hamstring strain, based on conventional clinical examination [13, 15]. These difficulties may be reflected in a conspicuously high injury recurrence rate, particularly within a few weeks after the return [4, 16, 20]. Evidently, there is a need for improved rehabilitation regimes, but also for relevant tests with increased discriminative and predictive ability [13, 15]. It is generally accepted that strength and flexibility are important performance variables that have bearing upon the propensity for hamstring injury [5, 17, 22]. A common characteristic for such tests appears to be that their relevance increases with their resemblance to challenges arising in practical situations. Thus, dynamic strength tests, particularly eccentric ones, seem to be more appropriate than static ones [6].

Decreased flexibility has already been identified as a risk factor for developing hamstring strains using presumably

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slow passive [3, 21], and active leg lifts [14]. It is hypothesized that active dynamic and even ballistic flexibility tests would be more sensitive to remaining anomalies and thus be better instruments for deciding when to return to sport. Another relevant aspect is the relationship between the physical and mental readiness to go back to sport on a pre-injury level of performance. This has been highlighted by the extended time period that can occur between when the strength and flexibility test values are restored and when the athlete actually decides that he or she is ready to return to sport [1]. It is hypothesized that an active ballistic flexibility test coupled with an estimation of subjective insecurity may, to some extent, also involve mental factors.

The purpose of this study was to establish the reliability and validity of an active ballistic hamstring flexibility test and to investigate if it could detect differences between previously injured and healthy legs at a point in the rehabilitation when conventional clinical tests, including a passive flexibility test, showed no difference and thus would have allowed return to sport.

Materials and methods

Subjects

Eleven healthy students of physical education, 6 women and 5 men (mean \pm 1 SD age 28 ± 7 years, body height 1.74 ± 0.07 m, body mass 68 ± 10 kg), with no earlier or current injuries in their low back or lower limbs, were tested. All students were active in various sports training with 4–7 training sessions a week, albeit not on an elite level. In addition, 11 elite athletes in different sports, 3 women and 8 men (21 ± 7 years, 1.77 ± 0.10 m, 74 ± 11 kg) with unilateral MRI-verified acute hamstring strain were included. All injuries occurred during running and were located in biceps femoris caput longum, except one that occurred during kicking and was located in semimembranosus. Seven of the eleven injuries occurred in the left leg. The right leg was the dominant leg in all participants. The mean time from the injury occurrence to the test was 7.8 weeks (range 3–17 w, SD 3.5 w). All subjects gave their informed consent prior to their participation. There were no drop outs in the study. Approval for the study was granted from the Regional Ethics Committee (Dnr: 2008/1320–31/2).

Test occasions

The students performed two tests of each leg on the same day, 30 min apart. All testing on the students was performed in the same format, with measurements of the right leg taken prior to those of the left leg. In the athletes, each

leg was tested at the time during recovery when a clinical examination of the injured leg revealed no signs of remaining injury. The clinical examination included palpation, strength, and flexibility tests as described below. Palpation was performed of both the medial and lateral hamstring muscles, from tuber ossis ischii to the insertions below the knee, in a prone position. No pain should be revealed from the injured muscle. A manual static strength test for knee flexion was performed in a prone position with the hip stabilized at 0° of extension. Resistance was applied at the heel at 0° , 45° and 90° of knee flexion. Strength was assessed on both legs simultaneously to allow inter-limb comparison. There should be no difference in strength between legs, and no pain should be provoked. Range of motion was measured with a flexometer during passive straight leg raise and should be close ($<10\%$ deficit) to that of the uninjured leg. Furthermore, in the end position, a static contraction of the hamstrings should not provoke pain [1, 13]. The test order was uninjured before injured leg. In addition, their uninjured leg was tested 8 days later. All subjects were requested not to participate in any vigorous exercise in the 2 days preceding testing. The same investigator supervised all tests.

Experimental set-up

The subject was positioned on a bench in a supine position with the axis of an electrogoniometer aligned with the bilateral axis of each of the hip joints (Fig. 1; video in Electronic supplementary material). The stationary lever of the goniometer was placed horizontally, and the moveable lever was aligned with and firmly attached with straps to the thigh. A knee brace ensured full knee extension of the tested leg. The contralateral leg and the upper body were stabilized with straps. In all tests, the foot of the tested leg was to be kept in a slightly plantar-flexed position. No warm-up exercises were done. All verbal instructions and explanations were standardized.

A flexibility test session consisted of an active straight leg hip flexion test immediately preceded by a passive straight leg hip flexion test. In the passive test, the examined leg was slowly raised by the investigator. The subject was instructed to relax and to say “stop” when the movement reached a maximal range of motion (ROM). The endpoint was reached when the subject reported a strong but tolerable stretching sensation in the hamstring musculature. One practice trial and three test trials were executed. In the active test, the instruction to the subject was to perform a straight leg raise as fast as possible to the highest point without taking any risk of injury. A set of three consecutive trials were performed, preceded by one practice trial with submaximal effort. After the three active trials, the subject was to estimate experience of insecurity

Fig. 1 The set-up for the active hamstring flexibility test. Starting position to the *left* and maximal hip flexion to the *right*

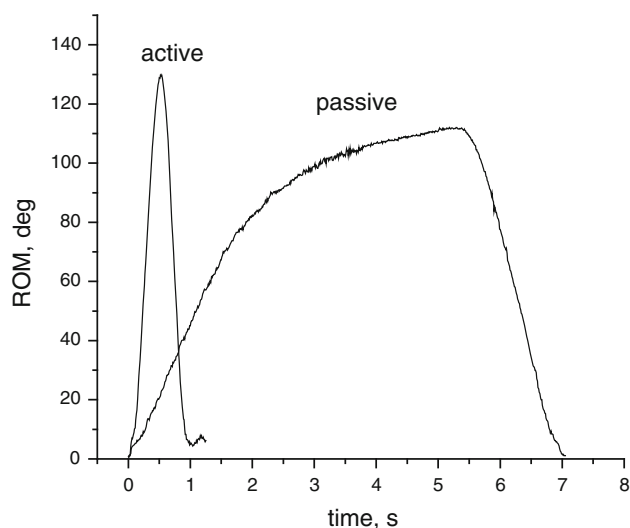
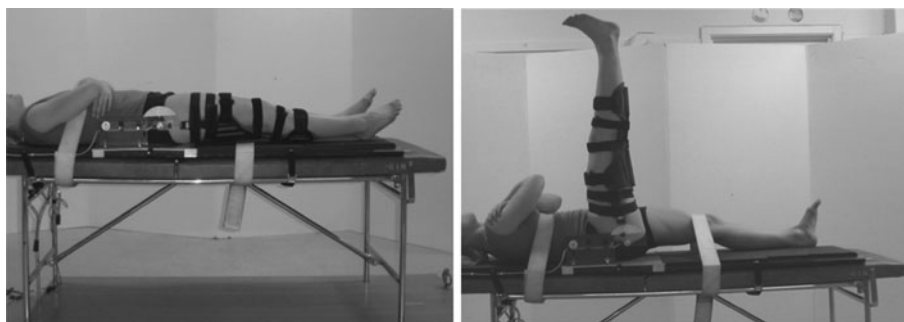


Fig. 2 Recordings of active and passive ROM in an uninjured leg

and pain on a VAS-scale, from 0 to 100. Flexibility, passive as well as active, was measured as the largest ROM of three consecutive trials, calculated from electrogoniometer data (Fig. 2). The mean angular velocity was calculated from electrogoniometer data recorded during the active test and the trial with the largest ROM was used for analysis. A hardware data logger and software were used to record and analyze the data (PASCO Scientific, USA).

Statistical analysis

The results are presented as means with standard deviations (SD) or with 95% confidence intervals (CI). Shapiro–Wilk’s *W* test was applied to examine normality in the distribution of data. To estimate the test–retest reliability of passive and active hip flexibility, intraclass correlation coefficient (ICC) [8] with the one-way random effects model of the measurements with 95% confidence interval (CI) and coefficient of variation (CV) [2] were used. Analysis of variance with ANOVA and post hoc Tukey test with Bonferoni correction and Student’s *t*-test were used to detect significant differences. Each participant acted as his or her own control, reducing variability and

increasing statistical power. The significance level was set at $P < 0.05$.

Results

No significant test–retest differences were observed (Table 1). Intraclass correlation coefficients (ICC) ranged 0.94–0.99 and coefficients of variation (CV) 1.52–4.53% (Table 1). On average, in all uninjured legs, the active flexibility was significantly greater (23%) than the passive flexibility (Table 1). The injured leg in the athletes showed smaller active (110 ± 14 vs. $119 \pm 12^\circ$, $P < 0.001$), but not passive (91 ± 18 vs. $91 \pm 19^\circ$, NS), flexibility when compared to the uninjured leg (Fig. 3). On the average, the mean angular hip flexion velocity in the students was similar for the left ($183 \pm 20^\circ/\text{s}$) and right ($190 \pm 32^\circ/\text{s}$) leg, and in the athletes, the uninjured leg showed significantly higher mean angular hip flexion velocity ($201 \pm 29^\circ/\text{s}$) than the injured leg ($175 \pm 34^\circ/\text{s}$).

Median values for insecurity estimation on the VAS-scale (0–100) was 52 (range 28–98) for the injured and 0 for the uninjured leg, respectively, in the athletes. The corresponding values for the estimation of pain were 0 (0–38) for the injured and 0 (in all cases) for the uninjured leg, respectively.

Discussion

The main findings of this study were that the new active ballistic hamstring flexibility test showed high reliability and proved to be applicable on athletes recovering from hamstring injury. Also, it appeared to be better able to detect remaining injury signs before return to sport than the commonly used clinical examination, including palpation, manual strength assessment and passive flexibility test. Thus, the active hamstring test could provide useful additional criteria for minimizing the risk for re-injury of the hamstrings upon return to pre-injury level of training and competition.

The new feature of the current test is that it is not only actively performed by the subject; it is also to be performed

Table 1 Mean (± 1 SD) range of motion (ROM) in degrees for the left and right leg of the students ($n = 11$) and the uninjured leg of the athletes ($n = 11$) on the different test occasions

	Students				Athletes	
	Left leg		Right leg		Uninjured leg	
	Passive	Active	Passive	Active	Passive	Active
1st test	89.8 \pm 13.2	116.4 \pm 10.2	90.7 \pm 13.9	116.0 \pm 8.7	90.7 \pm 18.9	119.4 \pm 11.6
2nd test after 30 min	92.9 \pm 14.7	115.7 \pm 10.0	91.7 \pm 14.1	117.5 \pm 7.7	–	–
2nd test after 8 days	–	–	–	–	90.2 \pm 18.7	118.1 \pm 9.5
ICC	0.94	0.95	0.99	0.95	0.98	0.96
95% CI	0.81–0.99	0.81–0.99	0.96–0.99	0.83–0.99	0.92–0.99	0.84–0.99
CV (%)	3.63	2.69	1.63	1.52	4.53	2.53
<i>P</i> -value	NS	NS	NS	NS	NS	NS

The respective intraclass correlation coefficients (ICC), coefficients of variation (CV) and *P*-values for the test–retests are presented below (NS non-significant)

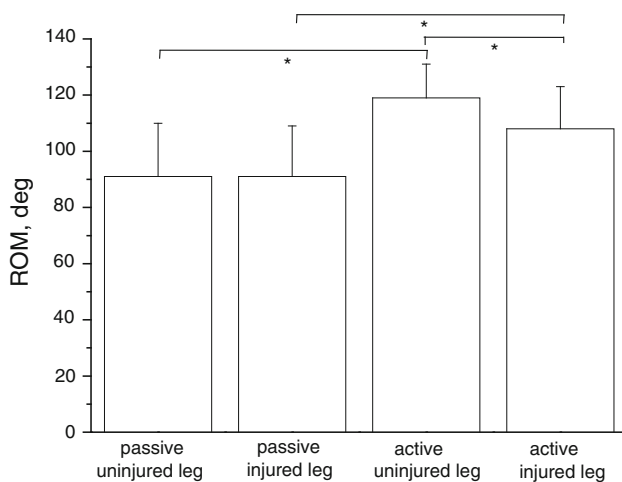


Fig. 3 Mean (± 1 SD) values for passive and active ROM in the uninjured and injured leg, respectively, in the 11 athletes. A significant difference ($*P \leq 0.05$, Student *t*-test)

in a ballistic manner, i.e. with the highest possible speed. Standard testing of hamstring flexibility consists of the straight leg being slowly moved by an experimenter into progressively more hip flexion until reaching a limit of discomfort for the subject [7, 9]. An alternative passive test exists, where the hip is kept at 90° of flexion and the knee passively brought into extension [7, 10]. The latter variant has also been performed with active knee extension, albeit with unspecified movement speed [11, 12]. It is noteworthy that keeping the hip at a fixed sub-maximal angle of 90° would preclude testing of subjects with extensive hamstring flexibility, such as those in the current study. In a recent paper, Henderson et al. [14] used active hip flexion range of motion in a prospective study on a group of English Premier League soccer players. The instructions and actual speed of movement were not reported, but it may be deduced from the considerably lower values

achieved for active hip flexion (mean 64°–71°) compared to our values (mean 116°–119°) that the movement was not performed in a ballistic manner. Interestingly, active hamstring flexibility came out as one of the significant factors in their logistic regression model predicting the likelihood to sustain a hamstring injury during the subsequent competitive season [14].

An evident question to ask is whether the new ballistic hamstring test, which is quite vigorous, is safe to apply even in previously injured subjects. So far we have not experienced any injuries in connection with the test. The number of subjects being tested is now exceeding 100. Even world class athletes have been tested and they have not hesitated to do the test on repeated occasions. Notably, the active test must not be performed before the time of rehabilitation when all clinical tests, including those of passive flexibility, indicate complete recovery.

Values of reliability for the active hamstring test were high (mean ICC 0.95–0.96, CV 1.52–2.69) and of the same order of magnitude as those for the passive test (0.94–0.99; 1.63–4.53). These values are similar to those earlier reported for passive and active tests of hamstring flexibility, with ICC values ranging from 0.83 to 0.92 [7, 12] and CV values from 0.9 to 4.9% [9, 14].

The ability of the test to discriminate between injured and uninjured side could be seen as a measure of the construct validity of the test. The outcome validity of the new active hamstring test remains to be demonstrated. A validation would require a prospective study where two groups of athletes would be followed with respect to recurrence of hamstring injury, one with decreased range of motion and/or insecurity in the active test before return to sport, the other without. However, ethically it would be questionable to perform such an experiment. A simplified version of the test, without goniometers, but with orthosis, has been used in our clinical work for some time; so far 30

athletes in various sports have been tested. The active test has been applied when the conventional clinical examination, including a passive flexibility test, showed no difference between the injured and uninjured leg. In 95% of the cases, there was a feeling of insecurity when performing the test with the injured leg. An additional 1–2 weeks of rehabilitation was then allowed and the test repeated, and so on, until no insecurity was reported. During the first 4 weeks after returning to full training and competition following the last active test performed with zero insecurity, there have been no re-injuries among these athletes (Askling et al. unpublished). In the literature, typical re-injury rates of 23–55% are reported during the corresponding period [4, 18].

Evidently, the active test poses a larger stress on the system and is accompanied by subjective decision on how big a challenge one can voluntarily expose one's musculo-tendinous system to, when compared to a passive flexibility test. We believe that the feeling of insecurity is central, not only in the test but also in the actual performance at a competitive level subsequent to return to sport activity. The possible coupling between subjective feeling of insecurity and actual status of the musculo-tendinous structures and their susceptibility for re-injury is beyond the scope of this study, but it may open for further research on the connection between physiologic and psychologic aspects of rehabilitation and return to sport [19].

The relatively small sample size is a limitation and further larger studies are desirable. The high reliability values for the active test are, however, encouraging. It may also be argued that using just one experimenter constitutes a limitation. In the active test, however, this influence is minimized by standardizing the instructions and using objective means of recording the range of motion. A ceiling effect may be reached in people with extreme hamstring flexibility, e.g. dancers, where there may be no or only minor differences between active and passive range of motion. Even though bilateral comparison is useful in most cases, i.e. comparing the injured to the healthy leg, it may be limited in specific cases where differences in flexibility between legs are to be expected beforehand, e.g. in hurdlers. In both these situations, however, the recording of insecurity in the active test may be the critical variable to use.

One goal of our ongoing studies of hamstring injuries, and ways to avoid them, is to come up with a simple test that can be used by practitioners in the field to secure safe return to sport activities. Even though the test evaluated in the current study uses rather basic equipment, it is usually not generally available. As described above, we have positive experiences from using the test without actually measuring the range of motion, but just relying on the subject's feeling of insecurity. We recommend, however, that a knee brace be used to avoid undue influence of

bending the knee during the test. Again, we want to emphasize that the active ballistic hamstring flexibility test should not be employed before all other tests indicate full recovery. If insecurity persists, the test should be repeated with an interval of about 2 weeks until no insecurity is reported and the athlete is allowed to return to sport.

Conclusions

The new active flexibility test appears to be reliable and valid for detecting deficits in athletes with hamstring strains and provides useful additional information to the common clinical examination before going back to full training and competition.

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Conflict of interest The authors declare that they have no conflict of interest.

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