The Effect of Previous Loading Cycles on the Reliability of a Clinical Measure of Hamstring Flexibility

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ABSTRACT

Purpose: The aim of the study was to determine the effect of successive repetitions of a measure of hamstring flexibility—the passive unilateral straight leg raise (SLR)—on the reliability of this measure. **Method:** Ten repetitions of the SLR were performed on nine healthy adults. Measures were quantified using an electromagnetic tracking system and standardized using a handheld dynamometer by stopping the SLR at a set end-point force. The 10 repetitions were analyzed as two blocks of five, and intra-class correlation coefficients—models (2,1) and (3,k)—were calculated for each block of data. **Results:** ICC values for both models were comparable between the two blocks of data. **Conclusion:** Previous loading cycles, to a set end-point force, are unlikely to improve the reliability of muscle flexibility assessment in a clinical setting.

Key Words: elasticity; muscle stretching exercises; range of motion, articular; reproducibility of results.

RÉSUMÉ

Objectif : L'objectif de cette étude était de déterminer l'effet de répétitions successives d'une mesure de la souplesse de l'ischio-jambier – l'élévation passive unilatérale de la jambe tendue (SLR) – sur la fiabilité de cette mesure. **Méthode :** Dix répétitions d'élévations passives unilatérales de la jambe tendue ont été réalisées chez neuf adultes en bonne santé. Les mesures ont été quantifiées à l'aide d'un système de suivi électromagnétique, puis normalisées à l'aide d'un dynamomètre manuel à un point prédéterminé de l'extrémité finale du mouvement. Les 10 répétitions ont été analysées en deux groupes de cinq, et des coefficients de corrélation intraclass – modèles (2,1) et (3,k) – ont été calculés pour chaque groupe de données. **Résultats :** La valeur du CCI pour les deux modèles ont été comparables entre les deux blocs de données. **Conclusion :** Il est peu probable que les cycles de charge antérieurs préétablis à l'extrémité finale du mouvement améliorent la fiabilité de l'évaluation de la souplesse musculaire dans un cadre clinique.

The stiffness of a muscle–tendon unit in vitro is reduced with cyclic loading.¹ This visco-elastic behaviour is related to the energy that is lost during loading/unloading, producing tissue hysteresis.² Previous in vivo studies that have addressed the visco-elastic behaviour of skeletal muscle have generally assessed load relaxation with static stretch application of more than 30 seconds in duration.^{3,4} The question remains, therefore, whether it is important to account for tissue visco-elasticity when assessing muscle flexibility, when the stretch is generally applied for a few seconds or less. This is particularly important for clinical research, where multiple successive measures are often taken.

The purpose of this study was to determine the importance of controlling for the short-term effects of previous loading cycles when measuring muscle flexibility, under conditions similar to those encountered in clinical

practice. Specifically, we aimed to assess the effect of successive repetitions, to a set end-point force, of a measure of hamstring flexibility—the passive unilateral straight leg raise (SLR)—on the reliability of this measure. As tissue relaxation has been shown to stabilize in vitro after approximately 4 to 5 loading cycles,¹ we hypothesized that over 10 repetitions of the SLR, analyzed as 2 blocks of 5, the reliability of the SLR would be improved for the second block.

METHODS

Nine healthy, university-aged adults (20–24 years; 7 women) participated, after providing informed consent. Ethics approval was obtained from the local ethics review board. The sample size was based on a target reliability of 0.9 (95% CI, 0.7–1.0), using five repeated measures for each block of testing.⁵

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Contributors: Both authors designed the study, collected the data, and analyzed and interpreted the data; drafted or critically revised the article; and approved the final draft.

Competing Interests: None declared.

Physiotherapy Canada 2012; 64(3):242–244; doi:10.3138/ptc.2011-18

Figure 1 (A) Single trial of the unilateral straight leg raise (SLR) of the right lower limb (subject ■, in B). Peak SLR = 79.7°; corresponding knee angle = 1.4°; peak force to produce the SLR = 45.8 N. (B) Scatter plot of the peak SLR values for all subjects, from all 10 trials.

SLR measures were acquired using a 3D electromagnetic motion capture system (TrakSTAR, Ascension Technology Corp., Milton, VT) with sensors affixed over the participant's left anterior superior iliac spine (ASIS) (sensor 1), the distal third of the right thigh (sensor 2), and the mid-point of the right leg (sensor 3). Peak SLR values were determined from the orientation of sensor 3 (leg) relative to sensor 1 (pelvis) in the sagittal plane. The orientation of sensor 3 (leg) relative to sensor 2 (thigh) was used to monitor knee flexion. The latter was necessary because we could not apply counter-pressure at the knee to prevent knee flexion during the SLR; doing so would have affected the recorded values from the dynamometer at the ankle, which were used to standardize the force used to produce the SLR.

Ten repetitions of the SLR were performed on the participants' right lower limbs. Participants lay supine on a treatment table while the tester passively flexed their lower limb at the hip. A handheld dynamometer (micro-FET, Hoggan Health Industries, West Jordan, UT), applied immediately proximal and posterior to the malleoli, was used to raise the lower limb. For the initial repetition, participants were asked to signal when they felt a strong but comfortable stretch in the posterior thigh, and the

corresponding force reading was matched for all subsequent repetitions. Rest between repetitions was limited to the time required to re-initialize data acquisition: less than 10 seconds. The 10 repetitions were then treated as 2 blocks of 5 repetitions to assess the effect of tissue hysteresis.

The intra-class correlation coefficient (ICC) for each block of data was calculated using two approaches⁶: ICC (2,1) was calculated to allow for generalizability beyond the current study (clinical perspective), and ICC (3,k) was calculated for a research-oriented perspective, where a motion capture system is the only rater of interest. A paired samples *t*-test (α -level 0.05) was used to compare the SLR measures between blocks. All statistical analyses were done using SPSS (PASW Statistics 18, SPSS Inc., Chicago, IL).

RESULTS

The data from a single SLR trial are illustrated in Figure 1A, showing a typical movement pattern.

Figure 1B shows a scatter plot of the peak SLR values for all subjects, from all trials. For the first block of five repetitions, the ICC values were 0.86 (model 2,1) and 0.97 (model 3,k), while for the second block these values were 0.92 (model 2,1) and 0.98 (model 3,k). The SLR values for the two blocks were not significantly different ($p = 0.12$), although this result may have been influenced by the relatively small sample size. The mean (SD) SLR was 62.8° (6.0°) and 64.2° (6.8°) for the first and second blocks respectively. The standard deviation for the measures of knee flexion angle at peak SLR, across all testing blocks, was 5.8°. The peak force readings from the handheld dynamometer deviated from the target values by 0.3% to 1.4%. The SLR movements were performed slowly, with a mean (SD) velocity of 4.0°/s (2.2°/s); peak movement velocity occurred near the start of all trials.

DISCUSSION

The findings of the current study do not appear to support the hypothesis that prior repetitions of a flexibility test may help to improve the reliability of subsequent measures when using a set end-point force. No significant difference was found between the SLR measures in the two blocks (see Figure 1B), and the ICC values were only slightly improved for the second block of 5 trials, a difference that is unlikely to be of clinical importance.

Previous *in vivo* studies assessing the effect of stretching on the hamstring muscle-tendon complex have demonstrated significant load-relaxation behaviour.^{4,7} The findings of the current study, however, may be explained by the fact that the effect of a muscle stretch on the passive energy absorbed by the muscle group (i.e., the area under the load-deformation curve) is quite short-lived.³

Some variability was present in the force used to perform the SLR, as measured by the handheld dynamometer, as well as in the knee angle measured at peak

SLR. The variability in each of these measures was relatively small, however, and is unlikely to have had a major impact on the outcome of the study. Similar sources of variability are also likely to exist in the clinical setting.

CONCLUSION

The findings of the current study suggest that previous loading cycles, to a set end-point force, are unlikely to improve the reliability of muscle flexibility assessment in a clinical setting.

KEY MESSAGES

What is already known on this topic

Substantial evidence exists for visco-elastic behaviour in muscle; the most clinically relevant findings focus on the acute effect of stretching in decreasing muscle stiffness and energy absorption.

What this study adds

This study examines whether tissue visco-elasticity is likely to influence the reliability of a clinical measure of muscle flexibility. Our findings suggest that cyclic pre-loading of the muscle-tendon complex in vivo is unlikely to have a clinically meaningful effect on the reliability of subsequent measures of muscle flexibility.

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