A 3-D KINEMATIC STUDY OF TWO POPULAR FLEXIBILITY TESTS

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INTRODUCTION

Flexibility is the intrinsic property of body tissues which determines the range of motion achievable without injury in a joint or group of joints (Holt et al. 1995). Although empirical evidence is not conclusive, it is generally agreed that flexibility is an important physiological variable in sport. Recently, a more rigorous scientific approach to the area of flexibility has been taken by researches who have directed efforts toward developing and validating improved static flexibility measurement procedures (Ekstrand et al., 1982) and addressed questions related to the importance of flexibility to sport and appropriateness of training (Ekstrand & Gillquist, 1982).
Goniometers are often used to measure the range of motion of the joints. These devices have been criticized and their reliability questioned. Part of the problem is with the instruments and part with the procedure for using them. To deeply understand the phenomenon of flexibility more accurate, precise, multiaxial measurements are desirable. By using an automatic motion analyzer (accuracy 1/3000 the field of view), it was the purpose of this study to perform a 3-D analysis of two popular flexibility tests. When possible, the data were compared with those obtained by standard goniometers.

METHODS

Five recreational athletes (age range: 24-40 yr.; height range: 1.70-1.76 m.) with normal lower limb function and physical examinations provided informed consent and participated in this study. They were required to perform the sit and reach test and the passive single-straight-leg raising test (table 1 and 2). Both the tests are usually used as a test for hamstring tightness even if the sit and reach test combines back and hamstring flexibility. Before the measurements the subjects warmed-up by performing 10 minutes of slow jogging, and slow stretching movements. Ten trials for each exercise were executed with one-minute rest period between trials. Kinematic data were recorded by means the ELITE optoelectronic system (Ferrigno & Pedotti, 1985) with a sampling rate of 100 Hz. Markers were placed on: C7, T3, T6, T9, T12, L3, and S1 to reconstruct the spine morphology; sacro-iliac spines, iliac crests, great trochanters, femoral condiles, malleola, and fifth metatarsal heads to mark the pelvis and the lower limbs; acromions, elbows and wrists to mark the arms.
The position of the internal joint centers of the hip, knee and ankle were estimated from the position of external landmarks using a mathematical model designed to match feasibility with accuracy and whose inputs were anthropometric and kinematic data. Due to the inevitable simplifications introduced, the use of the model is constrained to movement in which large rotation of body segments around their longitudinal axes are negligible like running, cycling and vertical jumping exercises. The back profile was modelled using a cubic spline.

STARTING POSITION	The subject sits on the floor with the legs extended and the feet together. The feet are in the neutral position.
MOVEMENT	The subject bobs forward four times trying to touch as far down the legs as possible and holds a maximum position.
CAUTION	The knee must remain extended and the foot in the neutral position

Table 1. The sit and reach test

STARTING POSITION	The subject lies in a supine position on a bench
MOVEMENT	The therapist moves the leg in an arc upward and toward the forehead as far as possible
CAUTION	The knee must remain extended and the back flat on the bench throughout the movement. Care must be taken to stabilize the pelvis

Table 2. The passive straight-leg raising test

RESULTS

Mean and standard deviation values of the hip range of motion during the sit and reach and the straight-leg raising test are outlined in table 3 and 4, respectively. Values ranged from 36.3 to 72.5 and from 35 to 57.7 degrees in the former and in the latter test, respectively.

	S1	S2	S3	S4	S5
RIGHT	72.5±1.6	51±0.7	42.1±0.6	62±1.1	58.2±1.5
LEFT	66.1±1.1	56.2±1	36.3±0.7	60.2±1	53.9±1.3

Table 3. The values are in degrees.

	S1	S2	S3	S4	S5
RIGHT	50.8±0.9	46.1±1	39.6±0.5	56.3±0.6	52.3±1.1
LEFT	46.3±1.2	49.2±0.7	35±0.6	57.7±0.4	49.2±1.2

Table 4. The values are in degrees

The results showed significant bilateral differences for most of the parameters examined suggesting that evaluative procedures requiring controlateral comparisons may be inaccurate.

During the sit and reach test the subjects were instructed to try to keep their knee extended and the foot in the neutral position. In Fig. 1 and 2 the knee and the ankle joint angles at the maximum stretch position for a representative subject are presented. As it can be seen in most of the trials the subject was not able to keep the knee completely extended.

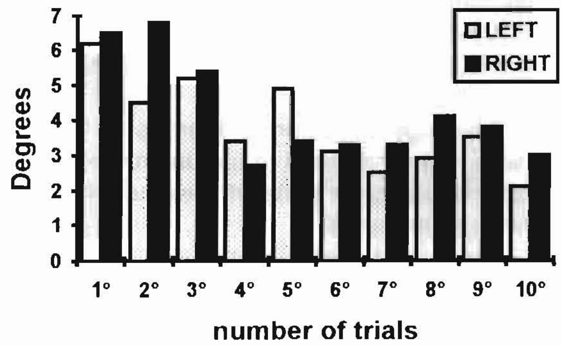

Fig. 1. Flexion of the knee joint at the maximum stretch position in the sit and reach test for a subject of this study. Zero degrees = knee extended.

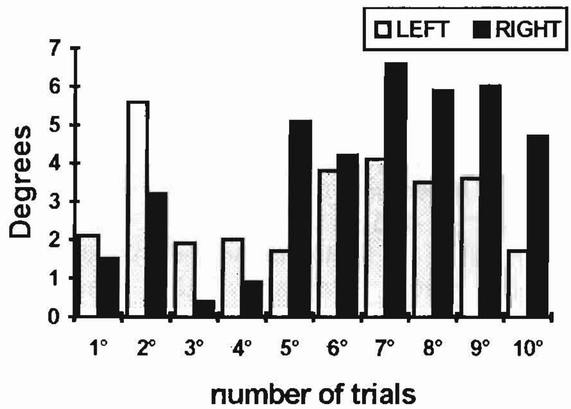

Fig. 2. Dorsiflexion of the ankle joint at the maximum position in the sit and reach test for a subject of this study. Zero degrees = foot in neutral position.

The dynamic examination of the sit and reach exercise revealed large intersubjects differences in the way to come to the full extended position evidentiating a different degree of spine mobility among the subjects.
Analyzing the straight-leg raising test the comparison with standard goniometer measurements showed differences up to 24 degrees in the hip range of motion. With regard to the sit and reach test the comparison with goniometry is not possible because the traditional protocol involves linear measurements of the distance between the fingertips and a zero mark on the floor and does not provide a direct quantification of range of motion in degrees (Twomey & Taylor, 1979).

CONCLUSION

Given the present state of knowledge and the results presented in this work, there are several basic reasons for recommending the use of an optoelectronic automatic motion analyzer for flexibility measurements:

1. It provides accurate, precise and multiaxial measurements.
2. It gives a good representation of the subjects during all the phases of the flexibility tests.
3. It provides a direct quantification of the range of motion in degrees.
4. It facilitates the work of the tester who no longer need to use instruments such as flexometers and goniometers and try aligning arms of these devices with segments while they are moving through the range.
5. It can provide the measurement of several joints and joint actions.
6. It allows the control of compensatory movements.
7. It allows a permanent record of the trials.
8. Considering the complexity of measurements performed and the amount of information available the method is not excessive time-consuming. In the present study it took less than 20 minutes for athletes preparation and trials performing.

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