Original article

Active knee range of motion assessment in elite track and field athletes: normative values

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Summary

Background: **flexibility is an important physical characteristic in athletes in terms of performance and injury prevention. Active Range Of Motion (AROM) was assessed in elite Greek track and field athletes.**
Methods: **prospective cohort study was carried out. In the period 2000-2010, the AROM was measured bilaterally with the Active Knee Extension (AKE) test during an in-season period with a goniometer in 127 athletes.**
Results: **male runners and jumpers had a higher mean AROM than throwers, but this result was not statistically significant. Female jumpers had a higher mean AROM than both runners and throwers, but the difference was also not statistically significant.**
Conclusion: **in athletes, mean posterior thigh muscle flexibility is likely to be between 72.3º and 73.9º. Posterior thigh muscle flexibility is associated with performance, the higher the AROM, the better performance is achieved athletes have generally high AROM, and this may be a result of their increased muscle flexibility. The normative values of posterior thigh flexibility may assist in better monitoring rehabilitation of the posterior thigh muscle injuries and be useful in pre-season screening of athletes' flexibility.**

KEY WORDS: flexibility, goniometry, posterior thigh muscles.

Introduction

Hamstring injuries are common in running sports and football, and can often be long term and debilitating. To reduce the morbidity of these injuries, effective prevention and management strategies are crucial. One factor that can influence performance and susceptibility to hamstring injury is flexibility[1-3]. Assessing flexibility is also useful in clinical decision making to classify the severity of muscle injuries[3-21]. Finally, flexibility is one of the main components that must be restored and improved during rehabilitation[3-5]. Clinicians require normative data for different demographic groups to assess clinically the risk of injury and set rehabilitation goals. There is currently a lack of normative data relating to the flexibility of the posterior thigh among elite track and field athletes.
The aim of the present study is to establish normative values in elite track and field athletes for posterior thigh flexibility. The Active Knee Extension (AKE) test is a reliable and valid assessment of posterior thigh flexibility that was used in this study[6].

Materials and methods

Elite track and field athletes competing with the Greek National Track and Field team were enrolled in a cohort study. The study protocol was approved by the Ethics Committee of the Greek Track and Field Federation, and all athletes gave their written informed consent to participate in the study[7]. All athletes were informed in detail about the study and were free to with-

draw at any time. All subjects signed an informed consent before they were included in the study, and all procedures were conducted according to the Declaration of Helsinki. The recruitment period extended from January 2000 to December 2010. A total of 127 (67 men and 60 women; mean age, 23.3±3.9 years; range, 18-36 years) elite athletes participated in the present study.
Goniometry was used to assess posterior thigh flexibility with the AKE test. All the athletes were always measured by the same physiotherapist who has several years experience, including experience in measuring posterior thing flexibility with the AKE test. In addition, the intrarater reliability was tested. The athletes were obliged to inform the sports and exercise (SEM) Physician of the Sports Medicine Centre about any complaints they had. The SEM Physician telephoned each athlete once a month to determine whether the athletes had developed any injuries. No changes or adjustments were made to the training schedule of the athletes or their nutrition habits.

Eligibility criteria

Our primary sample was 172 athletes, 45 of whom were excluded from the study. Sixteen were excluded prior and 29 during the study following muscle strains or low back pain (Tab. 1). In total, 127 athletes met our eligibility criteria: all were elite track and field athletes competing at international level, and were free of past medical history of hamstring, lumbar-spine or lower-extremity muscle or tendon injuries for the past six months.

Active knee extension testing

Each athlete underwent AKE testing three times over a 6-month period, and the average was used in all analyses. In particular, three time intervals were used in order to gain more precise results for normative values, as changes in each athlete's results may be present at different periods (pre-season, in-season). AKE was always measured during the in-season. The athlete was positioned supine in the 90/90 position (Fig. 1A) on an examination couch, with both knee and hip flexed to 90º. The opposite leg was placed flat on the couch with the knee fully extended and maintained in this position throughout the test. The athlete was then

Table 1. Athletes excluded due to current or previous hamstring strain and low back pain.

	Prior to study	During the study
Hamstring Muscle Strain	10	19
Low Back Pain	6	10
Total	**16**	**29**

Figure 1. The stationary arm of an inclinometer was aligned along the femur with reference point the greater trochanter of the femur; the axis of movement was placed at the lateral femoral condyle at the knee joint and the moving arm was aligned with the lateral malleolus. A) The athlete was positioned supine in the 90/90 position on an examination couch, with both knee and hip flexed to 90º. The opposite leg was placed flat on the couch with the knee fully extended and maintained in this position throughout the test. B) The athlete was then instructed to actively extend the tested knee until firm muscular resistance was felt, while the hip is maintained at 90º flexion.

instructed to actively extend the knee being tested through the full available ROM until firm muscular resistance was felt, while the hip is maintained at 90º flexion (Fig. 1B). The stationary arm of an inclinometer [a double-arm 30-cm clear plastic inclinometer (Lafayette Instrument Company, Lafayette, Indiana)] was aligned along the femur with reference point at the greater trochanter of the femur; the axis of movement was placed at the lateral femoral condyle at the knee joint and the moving arm was aligned with the lateral malleolus[1,8]. We measured angles in degrees, in both sides, representing the AROM [90/90 position = 0 degrees (inflexible); full knee extension = 90° (flexible)]. Room temperature was 23º C, and athletes did not undertake any warm up before the AROM measurement. During that day no training was allowed before the measurement. All the measurements took place between 16.00-20.00 local time, Greece.

Care was taken to ensure that the thigh stayed at 90°of flexion during the test, and all athletes received standardised instructions. Within-session intrarater reliability was established on the first 10 subjects as sufficient for clinical measurement (ICC=0.96); and although less relevant to calculation of responsiveness data and subsequent interpretation of the study findings, between-session intrarater reliability was similarly established as sufficient (ICC=0.94).
The reliability of the AKE test has previously been reported[9]. Two measures were taken, and the average at each measurement event used for the purposes of the present study. No subject reported any persistent discomfort or pain associated with their participation in the study. Throughout our follow-up, the athletes' training schedule remained unchanged. No hamstring or back injuries were reported during the 6 months data collection period for each of the remaining 127 athletes.

Statistical analysis

Each athlete underwent one AROM measurement every 2 months, so that each athlete was measured three times during a period of six months. The mean of these measurements was used in the present study. The mean and standard deviation AKE flexibility was calculated for the entire cohort and the three groups (runners/sprinters, jumpers, throwers). An intraclass correlation coefficient (ICC, 3.1) was used to analyze the intrarater reliability. The standard error of measurement (SEM) was calculated. AKE flexibility was compared between these subgroups and between men and women and the left and right leg using ANOVA with repeated measures. Statistical significance level was set at $p<0.05$. The 95% confidence interval of the mean was calculated, indicating the accuracy of this point-estimate (=mean+/- 2 x standard error, standard error = standard deviation/square root of the sample size). The 95% confidence interval of the distribution of scores was also calculated (=mean+/-2xSD).

Results

Table 2 shows the number of athletes competing in the various track and field events.
The ICC for intrarater reliability was greater than 0.7. Standard errors of measurement were between 1.0° and 3.4°.
When we investigated whether there was any evidence of an association of AROM with the athletes' main discipline, we found that male runners (dominant leg = 70.9°, non dominant leg = 70.6°) and jumpers (dominant leg = 70.9°, non dominant leg = 70.9°) had higher mean AROM than throwers (dominant leg = 69.2°, non dominant = 68.6°), but this result was not statistically significant (p=0.41, p=0.58, p=0.46, p=0.57, respectively). In addition, the mean AROM difference between male runners and jumpers was not statistically significant (p=0.98 on the dominant leg, and p=0.91 on the non dominant). Among female athletes, jumpers had higher AROM (dominant leg = 73.2°, non dominant leg = 72.3°) than both runners (dominant leg = 69.6°, non dominant leg = 69.5°) and throwers (dominant leg = 69.1°, non dominant leg = 69.5°), but the difference was also not statistically significant (p=0.112, p=0.09, p=0.24, p= 0.12, respectively). No significant difference was evident between the dominant and the non-dominant side nor between male and female athletes (p>0.05).
The mean, standard deviation and 95% confidence intervals of the mean and the distribution of AROM scores are shown in Tables 3 (males) and 4 (females). The 95% confidence interval of the mean generally is within 5-10°. For example, the largest interval is 63.8-73.4° for the male throwers non dominant side. However, the 95% confidence interval of athletes' AROM scores was much larger. For example, 95% of male runners had a dominant side AROM between 55.3° and 86.6°.

Table 2. Number of athletes competing in the various track and field events.

EVENT	ATHLETES
100 m-200 m	18
High Jump	10
Long Jump	10
Discus Throw	5
Long-Distance Running	6
Hammer Throw	6
400 m	15
Pole Vault	5
Shot-put	4
100 m hurdles	4
110 m hurdles	6
400 m hurdles	7
Triple jump	2
800 m-1500 m	10
Decathlon	7
Heptathlon	6
Javelin throw	6
TOTAL	**127**

Discussion

A combination of factors may explain differences in performance and injury risk between athletes. These include muscle strength, flexibility, and the balance between the posterior and anterior thigh muscle strength. Posterior thigh muscle flexibility is associated with performance: the higher the AROM, the better the performance achieved[6,10-12]. The present study

Table 3. Descriptive data for AROM among male athletes.

	Runners (n=37)		Jumpers (n=19)		Throwers (n=11)	
	Dominant	Non dominant	Dominant	Non dominant	Dominant	Non dominant
Mean	70.9°	70.6°	70.9°	70.9°	69.2°	68.6°
SD	7.8	7.8	8.0	8.0	7.8	8.0
95% CI (mean)	68.4-73.4	68.1-73.1	67.3-74.5	67.3-74.5	64.6-73.8	63.8-73.4
95% CI	55.3-86.5	55.0-86.2	54.9-86.9	54.9-86.9	53.6-84.8	52.6-84.6

Table 4. Descriptive data for AROM among female athletes.

	Runners (n=36)		Jumpers (n=11)		Throwers (n=13)	
	Dominant	Non dominant	Dominant	Non dominant	Dominant	Non dominant
Mean	69.6°	69.5°	73.2°	72.3°	69.1°	69.5°
SD	5.7	5.9	5.8	5.7	5.8	5.6
95% CI (mean)	67.7-71.5	67.6-71.4	69.8-76.6	68.9-75.7	66.3-72.7	66.5-72.5
95% CI	58.2-81.0	57.7-81.3	61.6-84.8	60.9-83.7	57.5-80.7	58.3-80.7

measured normative values for posterior thigh flexibility with the AKE test in elite track and field athletes. To our knowledge, this is the first study to investigate normative values for posterior thigh flexibility among elite track and field athletes.

Our data indicate that elite track and field athletes are likely to have mean posterior thigh muscle flexibility between 72.3° and 73.9° when tested with the AKE test. From the perspective of the clinically based sports and exercise physician, it is important to know how flexible the posterior thigh muscles of the elite athletes are because it can influence clinical examination, management, and follow-up of healthy or injured athletes. Therefore, in clinical terms, knowing the normal AROM of elite athletes could help to influence athletes' performance, posterior thigh muscle injury prevention, decision making regarding the severity of the injury, and finally monitoring rehabilitation by restoring flexibility to normal levels or improving it. Knowing normative values of the active knee range of motion can be a useful tool for coaches, athletes and sports medicine health professionals. Future studies could use this method to further investigate serial screening of hamstring flexibility pre- and post-competition and training and at different times during season to determine whether hamstring flexibility changes over time and whether this is related to injury.

The mean normative value for active knee range of motion in elite male and female track and field athletes in the present investigation is 70.31° ±1.36°. Lower values were reported by Hahn et al.[13] but they studied not elite athletes. Gabbe, Bennell and Finch[9] reported also lower AROM values in elite and community level Australian footballers. Elite athletes have generally high AROM, and this may be a result of their increased muscle flexibility[13].

Room and body temperature may affect flexibility[14], and therefore active knee range of motion measurements. In the present study, room temperature was kept constant, and warm-up was not performed before the AKE test. We wanted to use a well-known, easy to perform, accessible and cost effective measurement method. Goniometry is suitable, and can easily be adapted in a clinical setting. In the present study, measurements of knee AROM were performed using the Active Knee Extension Test, a commonly used field test with published test-retest and inter-tester reliability[6].

Some Authors do, however, consider the validity of goniometric measurements to be limited, since two dimensional goniometry is only an estimation of three dimensional flexibility[15]. Regarding active knee range of motion, no statistically significant differences were found between the dominant and the non dominant leg, in accordance with other studies[16]. Some difference in ROM between dominant and non dominant sides of the body exists in some motions other than knee extension. However, these differences are small and clinically not relevant[16]. According to the American Medical Association, a change of less than 10° in external rotation is not sufficient to be considered an impairment and a potential risk factor for injury[17]. Hahn et al.[13] found also no significant difference between left and right knee.

No significant differences were evident between male and female track and field athletes, similar to what found in previous studies[18]. No statistical differences between the sexes were also found for active knee extension by Cleffken et al.[19]. However, some studies report sex differences[13, 20], where active knee extension was significantly higher in women compared to men. This discrepancy may result from the higher muscle development of present day female athletes.

The current findings may have implication for hamstring injury prevention, classification and management. The main concern of athletes and coaches is performance, and posterior thigh muscle flexibility is related to it[10-12]. Moreover, in terms of hamstring injury prevention, flexibility is likely to have a critical role in the timing, frequency, recurrence and severity of posterior thigh muscle injury. Flexibility is a major component of fitness that must be restored and improved during rehabilitation. Knowledge of the normative values of posterior thigh flexibility may assist in better monitoring rehabilitation of the posterior thigh muscle injuries. Finally, normative values may be useful in pre-season screening of athletes' flexibility.

Limitations

We have investigated posterior thigh flexibility among a cohort of elite track and field athletes. Our data may not relate to athletes from other sports or of differing ages or training habits. We did not measure our own reliability in assessing AKE flexibility. However, we followed an established method and the physiotherapist was experienced in assessing AKE flexibility.
In conclusion, elite track and field athletes are likely to have posterior thigh muscle flexibility between 72.3º and 73.9º when tested with the AKE test. No significant differences were observed between genders, dominant and non-dominant leg or runners' throwers and jumpers.

What this study adds to existing knowledge: elite track and field athletes are likely to have higher AROM than the ones reported in the literature knowledge of the normative values of posterior thigh flexibility may assist in better monitoring rehabilitation of the posterior thigh muscle injuries. Normative values may be useful in pre-season screening of athletes' flexibility.

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