World Journal of Sport Sciences 3 (3): 226-230, 2010
ISSN 2078-4724

The Relationship Between Ankle Joint Flexibility and Squatting Knee Flexion Posture in Young Malaysian Men

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Abstract: Adequate flexibility in ankle dorsiflexion is necessary for normal performance of functional activities. In addition, it is considered to be a risk factor of falls for the elderly and sport injuries in healthy males. The aim of this study was to clarify the intrinsic factor influencing the squatting knee flexion posture by discriminant analysis and to investigate the utility of ankle joint dorsiflexion measurement using this posture in healthy males. Ninety one healthy male subjects were asked to squat with their heels down and they were divided into 2 groups: 65 subjects were assigned to the possible squatting group and the remaining to the impossible squatting group. The anthropometric characteristics of the subjects were assessed and the flexibility and movement range of the lower extremities were tested. To identify the intrinsic factor influencing the squatting knee flexion posture, a discriminant analysis was performed. The sensitivity, specificity and cutoff values for the factor were also evaluated. Analysis revealed that body weight and ankle dorsiflexion flexibility was significantly associated with the ability to assume the squatting knee flexion posture. The impossible squatting group showed a reduced ankle dorsiflexion. Thus, the squatting knee flexion posture is a useful, easy and objective method to measure ankle joint dorsiflexion flexibility.

Key words: Ankle joint % Flexibility % Squatting % Weight-bearing lunge test % Balance

INTRODUCTION

Flexibility is a physical fitness and is often evaluated by the joint range of motion. It is defined as "performance of smooth and extensive movement of body joints" [1]. Reports on the significance of flexibility have focused on contribution of preventing injuries and improvement of sport performance [2]. Adequate flexibility in ankle dorsiflexion is necessary for normal performance of functional activities such as maintenance of gait, stair climbing and rising from a chair [3, 4]. Limitation of ankle dorsiflexion is associated with gait parameters [5] and balance function [6]. In addition, it is considered to be a risk factor of falls for the elderly [7] and sport injuries in healthy males [8-10]. The measurement method described here is expected to enable the prediction of the risk factor, thus leading to the prevention of the risk of falls, sports injuries, etc. An easy and objective method to measure ankle flexibility is necessary in physical therapy practice.

The squatting knee flexion posture is adopted by workers on farms in welding units, automobile assembly plants, etc [11]. The squatting knee flexion posture can be described as a sitting posture with dorsiflexed ankles, deeply flexed knees and hips and a flexed torso, with the shoulder occasionally resting on the knee. A previous study reported that approximately 20% of Japanese failed to assume the deep squat posture perfectly on a Japanese-style toilet and noted that the movement of the left and right ankle joint differed during squatting [12]. In Olympic weightlifting, there is a change in the angular velocity, angular acceleration and absolute angle of left and right ankle segment during squatting [13]. The variations in squatting posture indicate high degrees of flexion of all the 3 joints of the lower extremities [14]. In particular, ankle dorsiflexion flexibility is significantly correlated with the maintenance of a stable squatting knee flexion posture. Furthermore, body mass index (BMI) was found to be correlated with the maximal knee flexion during squatting [15].

In this study, we were able to evaluate ankle dorsiflexion flexibility by a simple method based on the squatting knee flexion posture. However, it was necessary to clarify the influence of anthropometric characteristics and a flexibility of other joints on the ability to adopt the squatting knee flexion posture.

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The purpose of this study was to clarify the intrinsic factor influencing the squatting knee flexion posture by discriminant analysis and to investigate the utility of ankle joint dorsiflexion measurement using this posture in healthy males.

MATERIALS AND METHODS

Subjects: The subjects were ninety one (n=91) healthy male college students who signed the consent forms after the study procedure was explained to them in details. Their mean age was 21.0 ± 2.9 years; mean height, 170.8 ± 5.8 cm; body weight, 64.8 ± 6.9 kg; and mean BMI, 22.2 ± 2.4 kg/m^2. None of the subjects had musculoskeletal disorders in their lower extremity in the last 6 months.

Methods: The subjects were asked to sit in the squatting knee flexion posture with their heels down and arms crossed and to maintain the posture for more than 5 seconds and they were divided into 2 groups: possible squatting and impossible squatting. The former group comprised individuals who were able to squat and the latter group comprised those who were unable to squat.

Two points to be kept in mind while squatting were as follows:

- Both knees and feet should be brought together to the maximum possible extent throughout the deep squat and
- The thigh and calf should be in contact with each other (Fig. 1).

The anthropometric characteristics of the subjects were assessed and the flexibility and movement range of the lower extremities were tested. The anthropometric characteristics included body height, body weight and BMI. It was necessary to measure the flexibility of each joint of the lower extremities in the squatting knee flexion posture. Therefore, items reflecting the flexibility of each joint were measured by specific tests. The straight leg raise (SLR) test was used to measure hip flexibility. In the SLR test, the subject's leg-with the knee held straight- was raised parallel to the edge of the table with the subject in supine position and the hip flexion angle was measured. Heel-buttock distance (HBD) was measured as an indicator of knee flexibility [16]. HBD is the distance between the heel and the buttocks. The subject was placed in the prone position and HBD was measured using a tape measure with the subject's knee passively bent. The modified Thomas test was used to measure the flexibility of the hip and pelvis [17]. In the modified Thomas test, the subject sat at the end of a plinth and held both knees to the chest. The subject held one leg in maximal hip flexion with his arms, while the tested limb was lowered toward the floor. Flexibility was determined by measuring the hip flexion angle using universal Goniometer. Finger- floor distance (FFD) was measured as an indicator of trunk flexibility [18]. FFD is the distance between the fingertip and the floor when the subject bends in an upright standing position and extends his fingers towards the floor. Ankle dorsiflexion flexibility was measured using the weight-bearing lunge test [19]. A weight bearing lunge is the distance between the tip of the big toe and the wall when the subject lunges toward the wall. It was measured with tape measure placed on the floor.

Fig. 1: Squatting Knee flexion Posture

Statistical Analyses: Statistical analyses were performed with SPSS version 17.0. To examine the possible differences between the two squatting groups with regard to testing each parameter, we used either Student's t test (if the distribution of the data was not normal). A p value of less than 0.05 was considered as significant. Dependent variables for squatting knee flexion posture were analyzed by a stepwise linear discriminant analysis to determine their relative importance for differentiating between the two groups. To show the significant association of the measured items with the intrinsic factors influencing the deep posture, a receiver operator characteristic (ROC) curve was calculated. The curve was used to investigate the screening point at which the groups showed the most difference with regard to the intrinsic factors influencing the squatting knee flexion posture.

RESULTS

Of the 91 participants, 65 were determined to belong to the possible squatting group and the remaining 26 subjects to the impossible squatting group. Table 1 compares the anthropometric characteristics of the subjects and the flexibilities and movement range of the lower extremities in both groups. Significant differences were observed in body weight, right HBD and both right and left-weight bearing lunges ($p<0.005$). Table 2 shows the results of the discriminant analysis. The analysis revealed that left ankle dorsiflexion flexibility and body weight were significantly associated with the ability to adopt the squatting knee flexion posture. Ankle dorsiflexion flexibility, in particular, was strongly associated with this posture. ROC analysis was performed to investigate the association between ankle dorsiflexion flexibility and the ability to adopt the squatting knee flexion posture. Fig. 2 shows the ROC curves for the possible cutoff scores of the right and left ankle dorsiflexion flexibilities. The area under the ROC curves was 0.86 for the right side and 0.85 for the left side. The coordinates of the ROC curves show that the ankle dorsiflexion flexibility with weight–bearing lunge test that most accurately represents the squatting knee flexion posture was 10.75 cm for the right side (sensitivity 80%; specificity 81%) and 11.25 cm for the left side (sensitivity 80%; specificity 75%).

Table 1: Anthropometric characteristics of the subjects and the flexibilities and movement range of lower extremities in both groups

	Possible Group (n=65)	Impossible Group (n=26)	p value
Age (years)	20.9 ± 2.00	21.3 ± 1.80	0.556
Body Height (cm)	170.1 ± 5.50	172.8 ± 6.80	0.064
Body Weight (kg)	63.7 ± 6.50	68.63 ± 7.0	0.012*
Body Mass Index (kg/m^2)	22.0 ± 2.40	22.9 ± 2.20	0.211
Right Straight Leg Raise (°)	68.7 ± 7.40	65.0 ± 8.90	0.096
Left Straight Leg Raise (°)	67.5 ± 7.60	64.4 ± 10.1	0.120
Right Heel-Buttock Distance (cm)	5.0 ± 2.20	6.7 ± 3.20	0.019*
Left Heel-Buttock Distance (cm)	5.6 ± 2.70	7.0 ± 3.40	0.080
Modified Thomas Test Values for the Right Side (°)	9.2 ± 4.50	10.0 ± 4.10	0.521
Modified Thomas Test Values for the Left Side (°)	9.5 ± 4.70	10.0 ± 4.20	0.729
Finger- Floor Distance (cm)	3.2 ± 10.6	0.9 ± 11.4	0.455
Weight-bearing Lunge for the Right side (cm)	12.7 ± 2.30	8.6 ± 2.80	p<0.001**
Weight-bearing Lunge for the Left side (cm)	12.9 ± 2.30	8.1 ± 3.10	p<0.001**

*Significant difference between possible squatting and impossible squatting groups (p<0.05)

**Significant difference between possible squatting and impossible squatting groups (p<0.01)

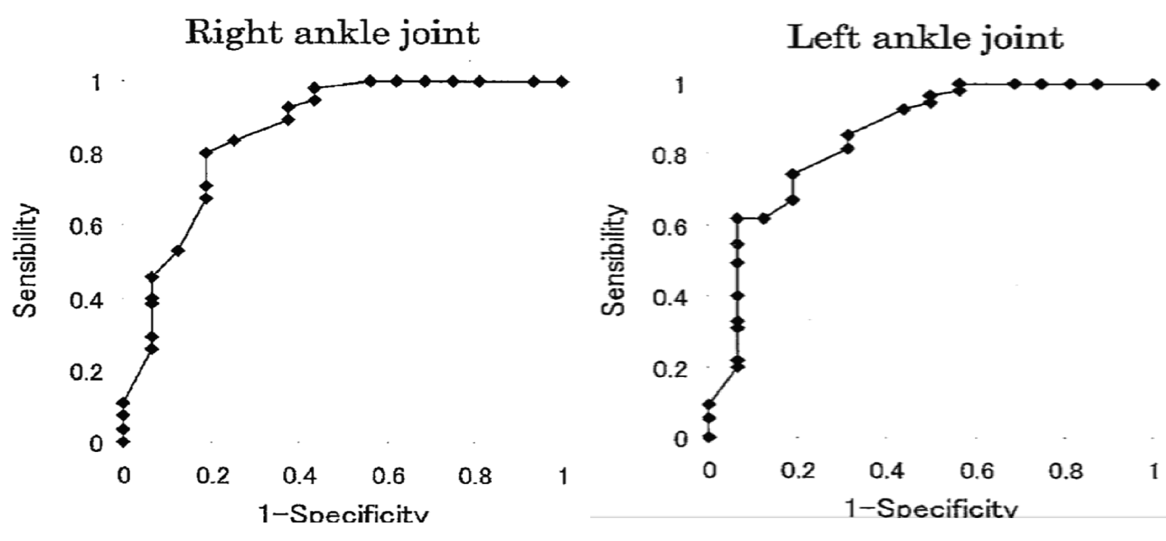

Fig. 2: ROC analysis

Table 2: Results of the discriminant analysis

	Model (a)
Predictor Variable (b)	Left Ankle Dorsiflexion Flexibility (0.94)
	Body Weight (-0.54)
Wilk's Lambda	0.57*
Canonical Correlation	0.65
Classification accuracy (c)	83% (81%)

(a) Discriminant model considering the anthropometric characteristics and flexibility variables

(b)Significant predictor variables, with standard discriminant coefficients in brackets

* p<0.05

(c)Percentage of cases correctly classified, with cross-validated classification accuracy shown in parenthesis

Figure 2 shows the ROC curves for the possible cutoff scores of the right and left ankle dorsiflexion flexibilities. The area under the ROC curves was 0.86 for the right side and 0.85 for the left side. The coordinates of the ROC curves show that the ankle dorsiflexion flexibility with weight–bearing lunge test that most accurately represents the squatting knee flexion posture was 10.75 cm for the right side (sensitivity 80%; specificity 81%) and 11.25 cm for the left side (sensitivity 80%; specificity 75%)

DISCUSSION

In this study, 28.5% of the subjects could not maintain the squatting knee flexion posture. Sugawara *et al*. [12] reported that approximately 20% of their Japanese subjects, 113 young and 79 middle-aged individuals, could not maintain the deep squatting posture. However, our study was conducted with only young Malaysian males. A detailed study on old age groups should be conducted in the future.

Various researches state that the ability to adopt the squatting knee flexion posture relates to ankle dorsiflexion flexibility [12, 14]. However, since the squatting knee flexion posture has also been shown to relate to anthropometric characteristics and the flexibilities of other joints, it was necessary to determine the factors which influence the squatting knee flexion posture. Therefore, it was aimed to determine the intrinsic factors that influence the squatting knee flexion posture. The discriminant analysis conceptually revealed that the squatting knee flexion posture was significantly correlated with ankles dorsiflexion flexibility and body weight.

It was assumed that the increase in ankle plantar flexion movement with the increase in the anterversion angle of the shank is the most influential intrinsic factor for the squatting knee flexion posture. The ankle plantar flexion moment causes front rotation of the shank and helps to stabilize the center of gravity, thus enabling the maintenance of balance [20].

Adopting the squatting knee flexion posture requires three-dimensional movement of the ankle joints. In this study, the subjects were instructed in the positioning of the foot and only movement in the sagittal plane was allowed. We think that lowering the degree of freedom of the lower extremities lead to the moderate discrimination percentage obtained by this evaluation method. In order to maintain balance in the case of limitation of ankle dorsiflexion, it is necessary to move the center of gravity forward by compensating with trunk and hip joint flexion. However, in this posture, it is impossible to keep the thigh in contact with the calf. Thus, limitation of ankle dorsiflexion makes it impossible to adopt the squatting knee flexion posture. Body weight is associated with the squatting knee flexion posture only to a slight extent. BMI was found to be correlated with the maximal knee flexion during squatting [15]. Body weight and BMI strongly related. We think that the increase of body weight also influences the knee flexion, thus making it impossible to keep the thigh in contact with the calf and to adopt the squatting knee flexion posture. However, the association could not be elucidated in detail because the thickness of the thigh and calf and percentage of body fat were not measured in this study.

A weight-bearing lunge of less than 11 cm indicates limitation of ankle dorsiflexion [9, 10]. Limitation of ankle dorsiflexion is associated with gait parameters during heel strike [5] and balance function [6]. In addition, it is considered to be a risk factor of falls for the elderly [7] and sports injuries [8-10]. Therefore, the measurement method described above is expected to enable the prediction of the risk factor, thus leading to the prevention of falls, sports injuries, etc. The method does not require any specific measuring instrument, meaning that the skill level and experience of the evaluator were not significant for the measurements. This study described an easy and objective measurement of ankle dorsiflexion for physical therapy practices and coaches.

ACKNOWLEDGEMENTS

I would like to thank Mr. S. Ganesh Pandian, coordinator and lecturers of Physiotherapy Department, Masterskill College of Nursing and Health, Sabah, Malaysia for their support and cooperation to initiate this research work.

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