Relationship between Vertical Ground Reaction Force during Isometric Squat at Various Knee Angles and Dynamic 1RM Back Squat in College-Aged Females

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Abstract

The purpose of this investigation was to systematically examine the relationship between a dynamic one repetition maximum (1 RM) squat exercise and five different knee angles (thighs are parallel to the floor (IsoPara), 90˚ (Iso90), 100˚ (Iso100), 110˚ (Iso110) and 120˚ (Iso120)) of maximum isometric squat exercises in recreationally trained college-aged females. Ten recreationally weight-trained healthy college-aged male subjects (mean age = 22.40 ± 2.01 years) were recruited from the University of Nebraska-Lincoln campus community for this study. A force plate was used to analyze the vertical ground reaction forces (GRFs) during the experimental sessions. For a maximum isometric squat, an order of the five angles was randomly assigned and the subjects performed two trials for each angle. The subjects were instructed to push an immovable bar fixed on a squat rack as fast and forcefully as possible for 5 seconds. The subjects were given a 3-5 minute break between experimental trials. Person product-moment correction coefficients revealed that the correlations between the 1RM weight mean values and mean maximum isometric squat peak vGRFs at all of the knee angles were significantly correlated ($p \leq 0.01$). In order to identify a multicollinearity issue among the independent variables, variance inflation factors (VIFs) were calculated. To address the high VIFs found for all of the isometric vGRFs at the various knee angles, only the highest correlation coefficient found (r = 0.95) during the knee angle at 90˚ was used for a linear regression analysis. The analysis generated a regression equation to predict 1RM dynamic back squat weight based on the peak ground reaction force during maximum isometric squat at the knee angle of 90˚ (Y = -114.97 + 0.73X) which explains 89% of variance to predict the 1RM squat weight (Adjusted R Squared = 0.89).

Purpose

Previous studies [1, 2] have investigated the relationship between exerted maximum forces during an isometric squat exercise and 1 RM weight lifted during a dynamic squat exercise. In these studies, the researchers used only male subjects, and the knee angles for the isometric squat were 30˚,60˚, 90˚, parallel, and120˚. In the current investigation, additional knee angles including 100 and110 were examined in college-aged females. By using the data from the study, the researchers will be able to gain a better understanding of the relationship between the force development characteristics of the dynamic and the static squat exercises. In addition, the isometric data may help identify how much resistance individuals should use when they start the dynamic squat exercise based on the forces measured during the static squat exercise without measuring the individuals' 1RMs which is typically a time-consuming process.

Methods

Table 1. Age and physical characteristics of subjects (n = 10)

Age (years) Mean ± SD	Height (cm) Mean ± SD	Body mass (kg) Mean ± SD	SMM (kg) Mean ± SD	Fat mass (kg) Mean ± SD	PBF (%) Mean ± SD
22.40 ± 2.01	169.03 ± 6.25	65.68 ± 7.17	28.69 ± 3.34	14.32 ± 4.57	21.57 ± 5.62

Note: SMM = Skeletal muscle mass, PBF = % body fat

Methods (cont.)

1 RM dynamic squat

- The subjects were allowed to use the most comfortable barbell carrying position and their stances. The distances between the toes and heels were recorded. These distances were used throughout the study for both dynamic and isometric squat trials.
- The subjects were instructed to use a light warm-up resistance that they could perform 5-10 repetitions at 40% to 60% of their perceived maximum strength. Next, the subjects performed 3-5 repetitions at 60%-80% of their perceived maximum strength.
- A conservative maximum resistance was attempted then if the attempt was successful, a rest period of 3-5 minutes was given before they attempted another trial. This process continued until they failed to complete a lift. The 1 RM value for the squat exercise was recorded as the last successfully lifted weight.
- Each subject's 1 RM was measured 2 separate occasions to assess its reliability.

Maximum isometric squat

- The subjects were asked to perform 5 different knee angles (i.e., the thigh is parallel to the floor, 90˚ knee flexion, 100˚ knee flexion, 110˚ and knee flexion of 120˚ maximum static squat exercise on the force platform. Prior to the data collection, they were provided 2 warm up trials (approximately 60% and 80% of their perceived maximum effort).
- The subject pushed an immovable weight training bar as hard and fast as possible in a self-standing half-rack. They were instructed to maintain the maximum effort of the push for 5 seconds. The order of the different knee angle maximum static squat trials were randomized.
- A goniometer was used to identify the specific knee angles. The subjects performed a total of two (2) maximum isometric squat trials for each knee angle. A 3-5 minutes of rest was provided before they attempted another trial.

Ground reaction force (vGRF)

- vGRF data were collected with a portable force plate
- Data were collected at the sampling rate of 1200 Hz.
- For the maximum isometric vGRF, over all mean peak vGRF was used (over the 5 seconds period).
- Each subject's vGRFs were measured 2 separate occasions

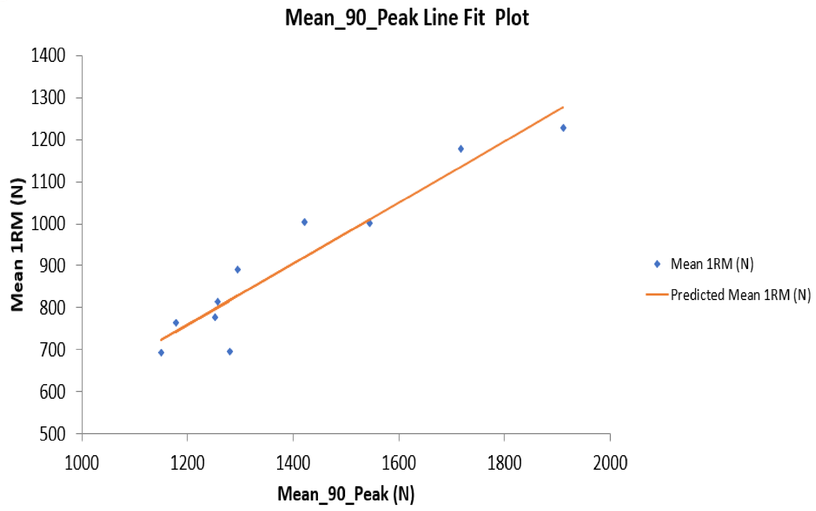
Results

TABLE 2. Relationships between isometric and dynamic squats (R values)

	Mean 1RM (N)	Mean_para_Peak	Mean_90_Peak	Mean_100_Peak	Mean_110_Peak	Mean_120_Peak
Mean 1RM (N)	1					
Mean_para_Peak	0.93†	1.00				
Mean_90_Peak	0.95†	0.98†	1.00			
Mean_100_Peak	0.93†	0.93†	0.97†	1.00		
Mean_110_Peak	0.86†	0.91†	0.94†	0.98†	1.00	
Mean_120_Peak	0.80†	0.89†	0.87†	0.87†	0.93†	1

Note: † = $p < 0.01$

Figure 1. Regression analysis between isometric and 1 RM dynamic squat weight



Conclusions

High correlations among the various knee angles were found ($p < 0.01$). Vertical GRFs obtained from a force plate during maximum isometric squats at the knee angle of 90˚ may be used to predict healthy college-aged females' dynamic 1 RM weights.

Practical Applications

Coaches, personal trainers, and clinicians may consider using the isometric force plate data when such a device is available to predict individuals' the dynamic 1RM squat value. The percentage of the predicted 1RM value may be used to prescribe an intensity of the exercise. This method to predict1RM may be a time-efficient and safe method for healthy college-aged females.

References

1. Demura, S., Miyaguchi, K., Shin, S., and Uchida, Y. (2010). Effectiveness of the 1RM estimation method based on isometric squat using a back-dynamometer. *Journal of Strength and Conditioning Research. 24*(10), 2742-2748.
2. Bazyler, C., Beckham, G., and Sato, K. (2015). The use of the isometric squat as a measure of strength and explosiveness. *Journal of Strength and Conditioning Research. 29*(5), 1386-1392.