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Relationship between Unilateral Leg Extension Strength and Dynamic Balance in Healthy Young Men

Fahri Safa Cinarli [1,*], Oğuzhan Adanur [2], Ozcan Esen [3], Magdalena Barasinska [4], Ladislav Cepicka [5], Tomasz Gabrys [5] and Raci Karayigit [6]

1 Department of Movement and Training Science, Faculty of Sport Sciences, Inonu University, Malatya 44280, Turkey
2 Department of Coaching Education, Faculty of Sport Sciences, Ondokuz Mayıs University, Samsun 55270, Turkey
3 Department of Sport, Exercise and Rehabilitation, Northumbria University, Newcastle-upon-Tyne NE1 8ST, UK
4 Department of Health Sciences, Jan Dlugosz University, 42-200 Czestochowa, Poland
5 Department of Physical Education and Sport, Faculty of Education, University of West Bohemia, 30100 Pilsen, Czech Republic
6 Department of Coaching Education, Faculty of Sport Sciences, Ankara University, Gölbaşı, Ankara 06830, Turkey
* Correspondence: safa.cinarli@inonu.com; Tel.: +90-422-3774940

Abstract: It is well known that the quadriceps muscle group is involved in activity during dynamic balance and that dynamic balance tests are an important feedback tool for predicting lower limb injuries. However, the relationship between maximum leg extension strength and performance in the Y Balance Test is not fully known. The aim of this study was to investigate the relationship between unilateral leg extension strength and dynamic balance in healthy young men. The study was conducted as a cross-sectional study. A total of 33 healthy men (mean age ± standard deviation = 21.21 ± 1.24 years) volunteered for this study. The participants' dynamic balance was determined with the Y Balance Test and unilateral one repetition maximum strength was determined by the leg extension machine. The same side was preferred for strength and dynamic balance measurements. Normalized reach, composite score, and absolute and relative strength values were analyzed for correlations. Linear regression analysis was used to determine whether strength values predicted the results of the Y Balance Test. There was a positive linear correlation between the strength values and normalized reach distances and composite scores (r ranges from 0.466 to 0.757; $p < 0.01$). The coefficients of determination showed that dynamic balance and strength (absolute and relative) performance are not independent parameters in healthy young men (r^2 = 21–57% explained variance). It was also found that strength values (absolute and relative) can predict balance. Our study confirmed the relationship between strength and dynamic balance. It can be said that especially the strength of the lower extremity has an acceptable effect on dynamic balance.

Keywords: dynamic balance; neuromuscular control; strength

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1. Introduction

Muscle strength and balance are necessary to move independently and safely in the activities of daily living [1,2]. It is mentioned that there is a relationship between balance and strength and that these parameters can explain each other [3]. It has been stated that muscle stiffness caused by force output can improve neuromuscular control by reducing the electromechanical delay associated with the spinal stretch reflex [4].

Balance requires the ability to integrate inputs from different sensory systems (i.e., somatosensory, visual, vestibular) and can be affected by musculoskeletal injuries, some neurological conditions, or ageing [5,6]. Falls are a common problem in general health and activities of daily living, especially in older people. It has been stated that understanding the relationship between strength and balance in older people and studies on this topic can contribute to the development of fall prevention and appropriate rehabilitation programs [7]. However, studying predominantly older populations leads to less scientific knowledge about the relationship between balance and strength in young adults. In balance and strength studies with adolescents and children, mostly individuals with certain specific disorders [8,9] or patients after ACL reconstruction [10] were studied. Along these lines, a recent review noted that there is a need for more research examining balance and strength performance in healthy young people [11]. The rationale for this statement is that there are conflicting findings regarding the interaction between balance and strength in healthy active adults and athletes. One study found a significant positive relationship between lower body strength and balance ($r = 0.360$, $p < 0.05$) [12], while another study found no significant relationship between normalized reach scores and knee extensor strength of the dominant leg in professional football players ($r = 0.06$, $p > 0.05$) [13]. This heterogeneous information has led us to investigate the interaction between basic athletic performance skills such as balance and strength.

Dynamic balance can be defined as the ability to meet postural demands in changing situations or successive conditions or to restore balance [14]. The Y Balance Test is the most commonly used dynamic balance test that measures the ability to control the body while maintaining stabilization of one leg. It is used to determine the possibility of injury in athletes, to identify bilateral asymmetries, and to identify functional limitations [15]. However, the Y Balance Test shows different results in terms of the scores obtained from three directions and the strength values for different muscle groups. For example, one study mentioned that there is a significant relationship between peak isokinetic knee extension torque and anterior reach asymmetry measured during the Y Balance Test, and that strength and balance performance can be used as important feedback for return to sport after ACL reconstruction [16]. Another study examined the relationship between concentric hip abductor strength and Y Balance Test scores. The authors found that hip abductor strength determined with an isokinetic dynamometer had a stronger correlation with posterior directions [17]. Furthermore, the results of the anterior Star Excursion Balance Test (SEBT) showed a positive correlation with the strength of the isometric hip flexors and extensors, while the results of the posterolateral SEBT were positively correlated with the strength of the hip abductors, extensors, and flexors [18]. So we can say that the type of contraction used during the strength test (isokinetic, isotonic, eccentric, etc.) and the different regions (knee, hip, etc.) directly influence the relationship between dynamic balance and strength.

For the above rational reasons, the aim of this study was to investigate the relationship between unilateral leg extension strength and dynamic balance performance in healthy young men. The hypothesis put forward in the research is as follows: "There would be a positive correlation between maximum strength and dynamic balance scores".

2. Materials and Methods

2.1. Study Design and Participants

The study was a cross-sectional design to investigate the relationship between strength and dynamic balance in healthy young men. Before the measurements of strength and dynamic balance, participants were asked not to exercise for at least 72 h and to maintain their daily eating habits. The study was completed with measurements taken at 3 different time points. The first time point was used to measure dynamic balance, the second to estimate weight for a maximum repetition (1RM), and the third to directly measure 1RM. An interval of 48 h was maintained between laboratory visits to avoid mutual interference of measurements and fatigue. The sample size was calculated a priori with the help of a sample size calculator (G-Power 3.1.9.3). An effect size of 0.59 was considered a reasonable and conservative starting point for determining the sample size [19]. Assuming that the type I error (α) was 0.05 and the power ($1-\beta$) was 0.80, the model indicated a minimum total sample size of 20 subjects, but allowing for a rate of missing participants, we decided to have a total of 33 participants. A total of thirty-three young healthy men (mean age ± standard deviation = 21.21 ± 1.24 years) were included in the study. To ensure homogeneity of participants, we studied individuals with similar physical activity and no history of systematic strength or power training. None of the subjects had a history of health limitations that might affect their ability to perform strength and balance tests. Inclusion criteria were an age of 18 to 30 years and the ability to have strength and balance to meet the requirements of the test. Exclusion criteria were subjects with chronic ankle instability, who underwent ACL surgery, or who experienced pain during strength and balance exercises. The study was approved by the Inonu University Ethics Committee (protocol number: 2022/3596). After the subjects were informed about the study, the consent forms were signed.

2.2. Unilateral Dynamic Balance

Dynamic balance ability was determined using the Y Balance Test. Before the measurements, the participants received instructions on how to perform the test and watched the video. With regard to the learning effect, 6 practices were performed before the formal measurements [20]. After completion of the test trials, a 2-min break was taken, followed by 3 test trials in each direction. All participants performed the Y Balance Test with their preferred side in the strength test. In one study, no significant differences in reach performance were found between the right and left leg in healthy participants [21]. Since bilateral asymmetry was not investigated in this study, strength and balance were used on the same side. The testing procedure was performed as previously mentioned [22]. When analyzing the data, the maximum reach distance for each direction was chosen. This value was normalized by limb length to avoid individual differences and expressed as a percentage. Limb length was measured from the anterosuperior iliac spine to the midpoint of the ipsilateral medial malleolus in the supine position. The maximum reach in each direction was divided by the limb length and multiplied by 100 to normalize the variable representing reach as a percentage of limb length [23]. In addition, the Y Balance Test Composite Score was calculated by dividing the sum of the maximum reach in the anterior, posteromedial, and posterolateral directions by three times the limb length of the individual and then multiplying by 100 [23].

2.3. Unilateral Leg Extension Strength

On the first visit, the 1RM was estimated using the multiple repetition method. The 1RM was estimated indirectly based on the number of repetitions [24]. This estimate was used at the second visit to determine the baseline load for the direct 1 RM test [25]. On the second visit, participants performed leg extensions at approximately 50% of their estimated 1RM (eight to ten repetitions), followed by approximately 75% of their estimated 1RM (three to five repetitions). The participants then did a repetition with a load that was close to their estimated 1RM. If this attempt was successful, the trial was repeated by increasing the load. If the attempt was unsuccessful, the load was reduced and the attempt was repeated [26]. However, as the weight discs on the leg extension machine are 2.5 kg, it is possible that the tests were performed slightly below or above the maximum repetition. It can be said that this situation can lead to a slight distortion of the results. There was a break of at least 2 min between 1RM trials. All measurements were performed within four to five trials. The maximum lifted load was recorded as 1RM for leg extension and the 1RM load was summed to represent the absolute strength (kg) and then the relative strength was calculated as absolute strength divided by body weight.

2.4. Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (version 24; IBM Corporation, Armonk, NY, USA). Homogeneity of the study data was determined with the Shapiro–Wilks test, which was used when the sample size was less than 50. The Pearson product-moment correlation coefficient was calculated between dynamic balance and leg extension strength (absolute and relative), and the variables were expressed as values with a 95% confidence interval (CI). The correlation was interpreted as follows: an *r* between 0 and 0.3, was considered small; 0.31–0.49, moderate; 0.5–0.69, large; 0.7–0.89, very large; and 0.9–1, near perfect for predicting the relationship [27]. Linear regression analysis was used to determine whether the strength scores predicted the Y Balance Test scores. All data are presented as mean ± standard deviation (SD) with 95% CI. The alpha level was accepted at $p < 0.05$.

3. Results

Participant characteristics and demographics were reported in Table 1 as mean ± SD with 95% CI. Participants' results on unilateral leg extension strength (absolute and relative) and Y Balance Test (3 directions and composite score) are shown in Table 2.

Table 1. Characteristics and demographic data of participants (*n* = 33).

Variables	Mean ± SD	95% CI
Age (years)	21.21 ± 1.24	20.81–21.63
Height (m)	1.74 ± 0.07	1.72–1.77
Weight (kg)	67.30 ± 9.12	64.27–70.48
BMI (kg/m^2)	22.04 ± 3.10	21.04–23.12

(BMI = Body mass index; SD = standard deviation; CI = confidence interval).

Table 2. Results of the unilateral leg extension test and the Y Balance Test (*n* = 33).

Variables	Mean ± SD	95% CI
Y Balance Test (% leg length)		
Anterior (A)	68.50 ± 6.88	66.26–70.86
Posterolateral (PL)	110.74 ± 14.97	105.80–115.46
Posteromedial (PM)	104.60 ± 13.08	100.15–109.23
Composite	96.66 ± 11.55	92.68–100.41
Leg Extension Test		
Absolute Strength	45.83 ± 7.25	43.41–48.18
Relative Strength	0.70 ± 0.13	0.65–0.74

(% leg length = (reach distance/limb length) × 100; Composite = [(A + PL + PM)/(leg length × 3)] × 100; Absolute Strength = maximum strength; Relative Strength = maximum strength/body weight; SD = standard deviation; CI = confidence interval).

Figure 1 shows a large and very large Pearson product-moment correlation between absolute strength and anterior reach (*r* = 0.757; 95% CI = 0.456 to 0.920), posterolateral (*r* = 0.585; 95% CI = 0.338 to 0.772), posteromedial (*r* = 0.605; 95% CI = 0.334 to 0.799), and composite score (r = 0.673; 95% CI = 0.442 to 0.823). Moderate and large correlations were found between relative strength and anterior reach (*r* = 0.658; 95% CI = 0.388 to 0.818), posterolateral (*r* = 0.466; 95% CI = 0.139 to 0.703), posteromedial (*r* = 0.470; 95% CI = 0.114 to 0.703), and composite score (*r* = 0.537; 95% CI = 0.209 to 0.741).

Linear regression analyses showed that leg extension strength was a significant predictor of performance in the Y Balance Test. Leg extension strength proved to be significantly predictive of three directional scores as well as the composite score (Table 3).

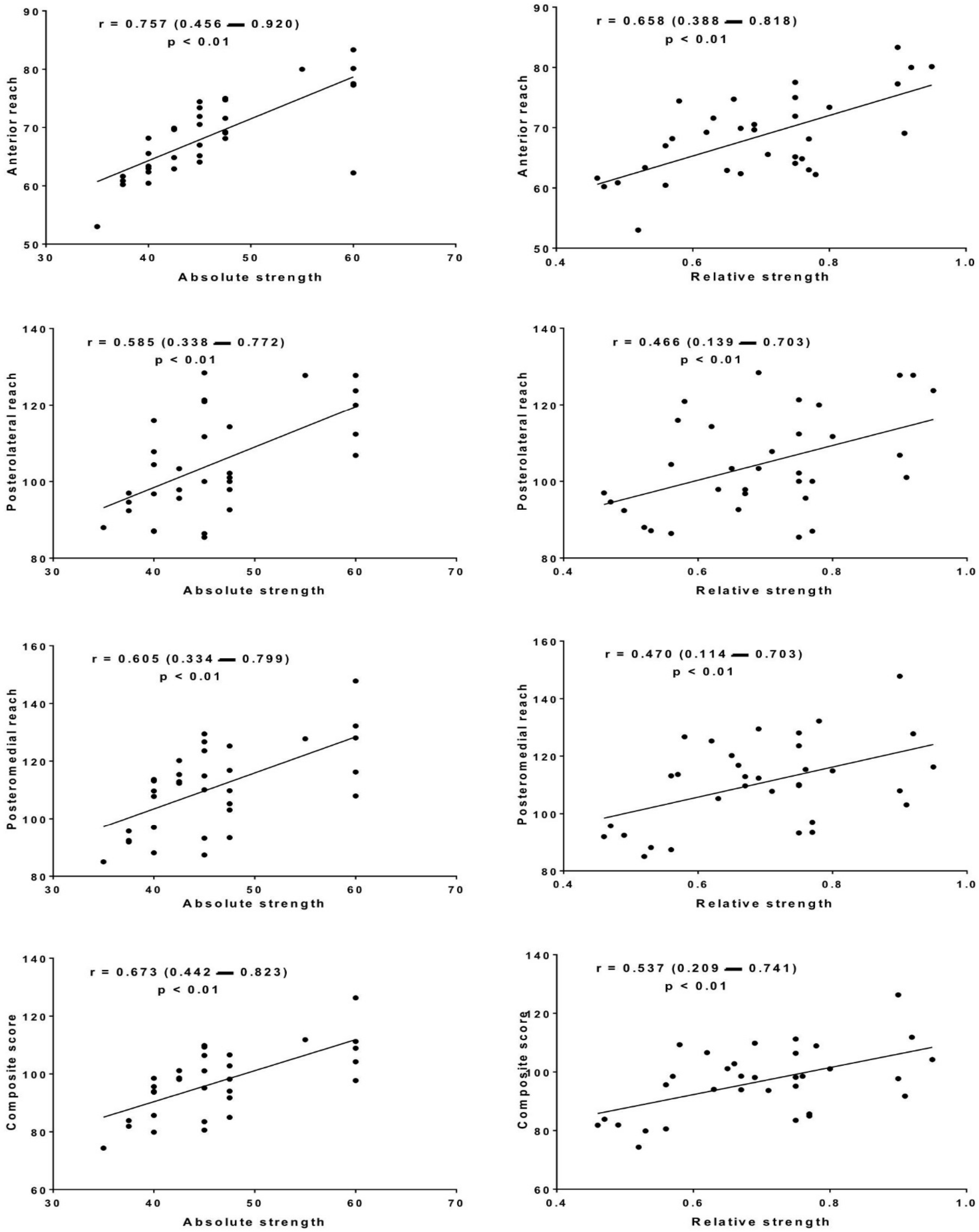

Figure 1. Scatter plots for unilateral leg extension strength (absolute and relative) and Y Balance Test 3 directions, and as well as composite scores and linear regression line with 95% CI.

Table 3. Results of the linear regression analysis for the unilateral leg extension strength and the results of the Y Balance Test.

Variables	r^2	Adjusted r^2	p Value
Anterior			
Absolute Strength	0.574	0.560	<0.001
Relative Strength	0.433	0.415	<0.001
Posterolateral (PL)			
Absolute Strength	0.366	0.346	<0.001
Relative Strength	0.221	0.196	0.006
Posteromedial (PM)			
Absolute Strength	0.342	0.321	<0.001
Relative Strength	0.217	0.196	0.006
Composite			
Absolute Strength	0.453	0.435	<0.001
Relative Strength	0.288	0.265	0.001

4. Discussion

This study investigated the relationship between unilateral leg extension strength and dynamic balance in healthy young men. The study found that all balance performances, including the three-direction score and the composite score used in the dynamic test, had moderate, large, and very large correlations with the absolute and relative 1RM strength scores. The results of the study show that the positive interaction between strength and dynamic balance is linear.

Lower limb strength is a fundamental component of sensorimotor function that supports mobility. Thus, a decrease in strength for movement-related activities may be associated with an increased likelihood of falls and a decrease in performance [28]. Chtara et al. [29] found that lower limb maximum isometric strength scores were significantly correlated with Y Balance Test directions, and a stepwise multiple regression analysis showed that power output explained between 21.9% and 49.4% of the variance in the Y Balance Test. In another study, a positive linear relationship was found between the distance in the Y Balance Test and the strength of the knee extensors in the anterior, posteromedial, and posterolateral directions ($r = 0.617$, $r = 0.599$, and $r = 0.565$, respectively) [19]. In our study, the explained variance between 1RM strength and dynamic balance seems to be compatible in this respect (21–57% explained variance). On the other hand, in some studies, one can find interesting results regarding strength and dynamic balance, which contradict our and many studies in the literature. For example, in a study examining the relationship between peak isometric torque of hip external rotation, abduction and extension, and Y-balance scores, it was found that only hip abduction was a predictor of the Y Balance Test score [30]. Furthermore, Thorbe et al. [31] found an insignificant relationship between the isokinetic concentric force of the ankle, knee, and hip groups and the dynamic balance values. They reasoned that the variance was not large enough to detect the relationship. Nevertheless, it can be said that increased strength capacity has a positive effect on balance performance. Mohammadi et al. [32] investigated the effects of a planned six-week lower and upper extremity strength training programme on static and dynamic balance in young male athletes. The authors observed significant training results for improving dynamic balance in the anterior (4.3%), posterolateral (6.1%), and posteromedial directions (6.6%). It can therefore be said that strength-based training methods have a direct influence on dynamic balance performance.

It can be mentioned that dynamic balance tests can also be a training strategy for strength development. Norris et al. [33] found that electromyographic (EMG) activity of the Vastus Medialis (VM) muscle exceeded the recommended threshold of 40–60% for strengthening effects during the test used in three aspects of the Star Excursion Balance Test (SEBT). In another EMG study, normalized peak EMG activity of the rectus femoris (RF) and vastus lateralis (VL) was greater than 74% in subjects with stable ankle groups in the posteromedial and posterolateral directions. In the same study, the activation values of the RF and VL muscles were found to be greater than 55% in the anterior direction [34]. In another study, high levels of activation of the RF (32–42.4%), VL (65.9–88.5%), and VM (63.2–97.1%) muscles were found with respect to three directions [35]. Examination of these results suggests that dynamic balance testing may be a training strategy for strength development. Furthermore, the quadriceps muscle is significantly active during the test and fires a large number of motor units. The relationship between knee extensor strength and dynamic balance found in the study can therefore be explained by the quadriceps muscle group having a high level of activity in all three directions identified during the Y Balance Test.

It is well known that the dynamic balance tests, especially the Y Balance Test, are used for performance monitoring of active athletes as well as for injury prevention and injury prediction strategy. A logistic regression study in Division I athletes found that players with a difference of 4 cm or more in the posteromedial direction between the lower extremities had a 3.86 higher risk of lower extremity injury (p = 0.001). The results show that players with below-average scores in each direction independently have almost twice the risk of injury [36]. In another study, anterior asymmetry was found to be associated with non-contact injuries (odds ratio: 2.33; 95% CI: 1.15–4.76) [37]. It was mentioned that quadriceps muscle strength is extremely active during the Y Balance Test, especially in the anterior direction, and the asymmetries found can be an important feedback for the injury [38]. For this reason, it can be stated that quadriceps muscle strength should be taken into account in tests such as the Y Balance Test or the SEBT, which measure high-level neuromuscular balance abilities, and that exercises for the quadriceps should be included in training programs.

The study has some limitations. Although an open kinetic chain exercise was preferred in the measurement of strength, balance performance was studied as closed kinetics. However, the reason for this situation was to determine lower limb strength with a more isolated exercise, especially in the quadriceps group. Another limitation is the determination of the 1RM for leg extension as the only lower limb strength. However, it can be said that the core muscle group is also very effective in terms of balance, especially with regard to the axia–appendicular connection. In future research, a deeper understanding can be gained through regression analyses by determining the strength of the muscle groups thought to contribute during the Y Balance Test.

5. Conclusions

The results of this study show that dynamic balance and strength scores are correlated in a healthy population. However, as mentioned earlier, the method or muscle group used to determine strength can affect the results. Linear regression analysis showed that the 1 RM leg extension strength best predicted the anterior aspect of Y balance. Furthermore, balance and strength abilities should not be considered separately, especially in healthy young people and active athletes, and it should be remembered that these parameters can influence each other.

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