Turkish Journal of Sports Medicine
Spor Hekimliği Dergisi

Turk J Sports Med. DOI: 10.47447/tjsm.0954

RESEARCH ARTICLE / ARAŞTIRMA MAKALESI

Trunk Isokinetic Strength and Dynamic Balance Explain More Than Half of the Variance in Single Leg Hop Performance

Gövde İzokinetik Kuvveti ve Dinamik Denge Tek Bacak Sıçrama Performansındaki Varyansın Yarısından Fazlasını Açıklamaktadır

Beyza Tayfur[1,2], Seher Karaçam[1], Figen Tuncay[3,4], Abdulhamit Tayfur[1,2]

[1]School of Physical Therapy and Rehabilitation, Kırşehir Ahi Evran University, Kırşehir, Türkiye

[2]Athlete Health and Thermal Rehabilitation Application and Research Center (SAUTER), Kırşehir Ahi Evran University, Kırşehir, Türkiye

[3]Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Kırşehir Ahi Evran University, Kırşehir, Türkiye

[4]Geothermal Source–Based Rehabilitation Center (JEOKAREM), Kırşehir, Türkiye

ABSTRACT

Objective: The single-legged hop for distance (SLHD) is a functional test widely used to assess lower limb performance and readiness for return to sport. While lower limb strength and balance are known contributors to SLHD performance, the influence of trunk function has received limited attention. To investigate the relationship between trunk strength, dynamic balance, and SLHD performance in healthy young adults.

Materials and Methods: Twenty-nine recreationally active participants (22.5±1.7 years; 16 females) underwent isokinetic trunk flexion and extension strength testing, dynamic balance assessment using the Y-Balance Test, and SLHD testing. Pearson correlations and multiple linear regression were used to identify predictors of SLHD performance.

Results: SLHD performance was significantly correlated with trunk extension strength ($r=0.60$, $p=0.001$), trunk flexion strength ($r= 0.42$, $p= 0.024$), posteromedial balance ($r= 0.47$, $p= 0.002$), and posterolateral balance ($r= 0.54$, $p= 0.002$). In the final regression model, trunk extension strength ($\beta= 0.504$, $p= 0.001$) and posterolateral balance ($\beta= 0.439$, $p= 0.003$) emerged as significant predictors, together explaining 54% of the variance in SLHD (R^2=0 .54, $p< 0.001$).

Conclusion: Trunk extension strength and posterolateral dynamic balance are significant contributors to SLHD performance in healthy individuals. These findings highlight the importance of trunk function and multidirectional balance in dynamic functional tasks and may inform training and rehabilitation strategies targeting performance and injury prevention.

Keywords: Trunk strength, dynamic balance, single-legged hop test, functional performance, neuromuscular control

ÖZ

Amaç: Tek Bacak Sıçrama Testi (TBST), alt ekstremite performansını ve spora dönüş uygunluğunu değerlendirmek için yaygın olarak kullanılan fonksiyonel bir testtir. Alt ekstremite kuvveti ve denge, TBST performansına katkı sağlayan faktörler olarak bilinmektedir; ancak gövde fonksiyonunun etkisi sınırlı şekilde incelenmiştir. Bu çalışmada, sağlıklı genç yetişkinlerde gövde kuvveti, dinamik denge ve TBST performansı arasındaki ilişki araştırılmıştır.

Gereç ve Yöntem: Rekreasyonel olarak aktif yirmi dokuz katılımcıya (22.5±1.7 yaş; 16 kadın), izokinetik gövde fleksiyon ve ekstansiyon kuvveti testi, Y-Denge Testi ile dinamik denge değerlendirmesi ve TBST testi uygulandı. TBST performansının yordayıcılarını belirlemek amacıyla Pearson korelasyonları ve çoklu doğrusal regresyon analizi kullanıldı.

Bulgular: TBST performansı, gövde ekstansiyon kuvveti ($r=0.60$, $p=0.001$), gövde fleksiyon kuvveti ($r=0.42$, $p=0.024$), posteromedial denge ($r=0.47$, $p=0.002$) ve posterolateral denge ($r=0.54$, $p=0.002$) ile anlamlı şekilde ilişkili bulundu. Regresyon modelinde, gövde ekstansiyon

Received: 21.07.2025 · **Accepted:** 10.11.2025 · **Published:** 31.07.2026

Correspondence: Beyza Tayfur · School of Physical Therapy and Rehabilitation, Kırşehir Ahi Evran University, Kırşehir, Türkiye · beyza.tayfur@ahievran.edu.tr

Cite as: Tayfur B, Karaçam S, Tuncay F, Tayfur A. Trunk isokinetic strength and dynamic balance explain more than half of the variance in single leg hop performance. *Turk J Sports Med*. 2026; https://doi.org/10.47447/tjsm.0954

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes (http://creativecommons.org/licenses/by-nc/4.0/).

kuvveti (β=0.504, p=0.001) ve posterolateral denge (β=0.439, p=0.003) anlamlı yordayıcılar olarak öne çıktı ve TBST performansındaki varyansın %54'ünü açıkladı (R^2=0.54, p<0.001).

Sonuç: Gövde ekstansiyon kuvveti ve posterolateral dinamik denge, sağlıklı bireylerde TBST performansının önemli belirleyicileridir. Bu bulgular, dinamik fonksiyonel görevlerde gövde fonksiyonu ve çok yönlü dengenin önemini vurgulamakta olup, performans geliştirme ve sakatlanma önleme odaklı antrenman ve rehabilitasyon stratejilerine rehberlik edebilir.

Anahtar Sözcükler: Gövde kuvveti, dinamik denge, tek bacak sıçrama testi, fonksiyonel performans, nöromüsküler kontrol

INTRODUCTION

Single-legged hop for distance (SLHD) test is one of the most commonly used tests to assess lower limb power, function and neuromuscular control [1]. The SLHD involves standing on one leg and jumping forward aiming for maximal distance. The participant should land on the same leg without losing balance. The distance is then measured to have an understanding of the lower limb function. The SLHD is simple and clinically applicable, with a high between-assessor and between-day reliability [1]. The test can be used to assess functional performance, lower limb asymmetries, evaluate rehabilitation progress, return-to-sport readiness following different types of injuries, and predict potential risks associated with lower limb injuries [2-4]. Considering its cost-effectiveness and clinical importance, the SLHD is commonly used in clinical settings.

Lower limb strength and balance are primary contributors to SLHD performance [4-6]. Quadriceps strength and rate of torque development may predict up to 25% of variance in hop distance following anterior cruciate ligament reconstruction (ACLR) [4]. However, the role of other key muscle groups-particularly those involved in stability and force transmission, is often overlooked. Trunk strength and stability may play a critical role in SLHD performance, as the test requires efficient transfer of force generated by the lower extremity through a stable trunk to the ground and back. The trunk significantly influences lower limb energetics and biomechanics [7-9], and deficits in trunk neuromuscular control have been associated with an increased risk of knee injury [10]. Furthermore, it was reported that a trunk position may influence on decreasing stiffness in the knee and hip joints, and therefore might be a strategy for achieving a softer landing pattern [9]. Given its impact on lower limb function, the trunk's contribution to SLHD performance may be as important as that of the lower limb musculature.

Landing stability is another critical component of SLHD performance. Beyond serving as a criterion for successful execution, postural stability and dynamic balance are significantly correlated with hop distance [6, 11]. SLHD requires not only the ability to generate sufficient force for take-off but also the neuromuscular control necessary for a stable landing on one leg. Deficits in dynamic balance can lead to instability upon landing, thereby reducing hop distance and overall performance. Better dynamic balance contributes to improved landing control and longer hop distances, enhancing SLHD results [6, 11].

Understanding the role of trunk strength and dynamic balance on SLHD performance may offer valuable insights for rehabilitation and performance enhancement strategies. Therefore, the aim of this study was to examine the contribution of trunk isokinetic flexion and extension strength, as well as dynamic balance, to SLHD performance.

MATERIAL AND METHODS

Study design

This cross-sectional study was conducted on healthy individuals, with all measurements obtained during a single testing session between April 2025 and May 2025.

Participants

Individuals aged between 18 and 65 years, corresponding to the accepted adult age range, were eligible for inclusion in the study. Participants were excluded if they had a prior history of lower extremity or spinal surgery, or any neurological or orthopedic condition that could potentially affect balance or functional performance.

Demographic characteristics of all participants were obtained through a standardized demographic information form. The form included questions regarding age, sex, height, mass, dominant side, lower limb length on the dominant side, and the Tegner Activity Scale. The Tegner Activity Scale is a scoring system that rates individuals' physical activity levels on a scale from 0 to 10. A score of 0 indicates complete inactivity due to injury or dysfunction, or being on medical leave, while a score of 10 reflects participation in high-level competitive sports at the national or elite level [12, 13].

The procedures followed were in accordance with the ethical standards of human experimentation outlined in the 1964 Declaration of Helsinki and its subsequent revisions. The study was approved by the relevant institutional ethics committee. All participants were fully informed about the study, and written informed consent was obtained from each participant prior to their inclusion.

Testing procedures

The SLHD was used to assess lower extremity strength and balance. Dynamic balance was measured using the Y-Balance Test, and trunk muscle strength was measured with a computerized isokinetic dynamometer. The testing order was randomized for each participant. Participants were given at least 2-minutes of rest between the tests [14].

Y-Balance Test

The Y-Balance Test (YBT) was used to assess dynamic balance. This test has demonstrated excellent inter-rater reliability across all three directions-anterior (ICC= 0.99; 95%CI: 0.99- 1.0), posteromedial (ICC= 1.0; 95%CI: 1.0), and posterolateral (ICC= 1.0; 95%CI: 0.99- 1.0) as well as for the composite score (ICC= 1.0; 95%CI: 1.0) [15].

The YBT was administered in accordance with the protocol previously described [16, 17]. The primary aim of the test is to evaluate dynamic balance by requiring the participant to maintain single-leg stance stability while reaching as far as possible with the contralateral leg in three directions: anterior, posteromedial, and posterolateral. Prior to testing, participants received verbal instructions and a visual demonstration of the test. They were allowed two practice trials with corrective feedback to ensure proper performance [18]. Testing commenced with the participant's dominant lower limb. Participants were instructed to reach as far as possible in the anterior direction first, followed by the posteromedial and posterolateral directions, tapping their foot lightly on the ground at the furthest reach point. Approximately one minute of rest was provided between trials.

Anterior, posteromedial, and posterolateral reaches were performed with the non-dominant leg, while standing on the dominant side. The order of the directions was randomized for each participant. The starting position involved aligning the dominant foot on the stance plate with the toes positioned at the red line, while the contralateral foot lightly touched the ground just behind the plate. The free leg was extended in the target direction, pushing the reach indicator as far as possible while maintaining balance. The free leg was then returned to the starting position in a controlled manner. Participants were prohibited from using the free foot to touch the ground for support, resting on the reach indicator, or pushing the indicator to gain leverage.

All measurements were recorded from the red line on the stance plate to the nearest 0.5 cm, as read directly from the testing device. Each reach direction was repeated three times, and the average distance was calculated to represent the reach distance. The results were normalized relative to the participant's leg length to compute a composite reach distance. Lower limb length was measured in the supine position from the anterior superior iliac spine (ASIS) to the most distal point of the medial malleolus using a tape measure(Hoechstmass Balzer, Sulzbach, Germany).

Single Leg Hop Test

Each participant was asked to stand on one leg, placing their heel on a predetermined mark. They were then instructed to jump forward as far as possible and land on the same leg in a controlled manner [1]. All measurements were performed using the dominant leg. Participants' dominant side was identified by asking which leg they preferred to use for kicking a ball. Prior to the jump, participants were allowed to swing their arms freely and use a countermovement of their choice. During landing, while the researcher marked the point of heel contact, participants were instructed to maintain foot contact with the ground. The horizontal distance between the initial heel position and the landing heel mark was measured in centimeters using a standard tape measure (Hoechstmass Balzer, Sulzbach, Germany). The test was repeated if the participant was unable to maintain balance on the landing leg for at least 2 seconds. Participants were given three practice attempts, followed by three recorded valid jumps. A 30-second rest interval was provided between each jump. For data analysis, the average distance of the three valid jumps was used. The results were normalized relative to the participant's leg length. Lower limb length was measured in the supine position from the ASIS to the most distal point of the medial malleolus using a tape measure (Hoechstmass Balzer, Sulzbach, Germany).

Isokinetic Testing Procedure

Trunk strength was measured with an isokinetic dynamometer which provides valid and reliable results[19]. Participants were positioned in a standing posture on the TEF modular component of the Cybex NORM isokinetic dynamometer. The axis of rotation was aligned with the intersection of the midaxillary line and the lumbosacral junction, approximately 3.5 cm below the iliac crest. Heel placement was secured in footplate cups, and footplate height was adjusted to align the subject's vertical axis with the dynamometer's axis using a rubber alignment pointer.

The pelvis was loosely strapped at the anterior superior iliac spines, and popliteal, thigh, and tibial pads were adjusted to stabilize the lower limbs in ~15° knee flexion. Subjects were positioned against the sacral pad, with fore-aft alignment fine-tuned to match the rotational axis. Scapular and chest pads were then secured to ensure upper body stabilization. Proper alignment was confirmed through active range-of-motion checks, after which positional measurements (e.g., footplate height, pad positions) were recorded in the Cybex software.

The anatomical zero position (upright standing) was defined as the reference for trunk range of motion, preset to 90° (90° flexion to 0° extension), with mechanical stops in place.

Each participant completed six submaximal continuous concentric trunk flexion and extension contractions at 60°/sec as a warm-up. The warm-up set was followed by two minutes of rest. Following, six repetitions at maximal effort was performed at 60°/sec. Participants received visual feedback and verbal encouragement throughout testing. The highest peak torque recorded across the six repetitions was used for analysis.

Statistical analysis

The assumption of normality was tested using the Shapiro-Wilk test. Pearson correlation analysis was used to examine the associations between variables. Parameters affecting SLHD was identified through linear regression analysis. The dependent variable of the study is the SLHD while the independent variables are trunk flexion and extension muscle strength and YBT results. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 29.0 (Armonk, NY: IBM Corp.; 2016).

Based on the correlation coefficient of 0.43 reported by Granacher et al. for the correlation between balance and trunk muscle strength, the required sample size was calculated as 29 participants, assuming a statistical power of 0.80 and a significance level of 0.05 [20]. In addition, a supplementary power analysis was conducted for the regression analysis to ensure adequacy of the sample. Using prior data from Shahtahmassebi et al., who reported an R^2=0.508 for the association between trunk muscle strength and functional performance, the required sample size was calculated in G*Power 3.1 as 18 participants for two predictors (one strength and one balance variable) ($\alpha = 0.05$, power = 0.80)[21].

RESULTS

A total of 29 participants (age: 22.48±1.70 years, 16 females, height: 169.0±8.93 cm, mass: 69.34±18.88 kg, BMI: 23.93±4.48 kg/m^2) were included in the study. The mean Tegner score was 4.55±1.09 for physical activity level. Descriptive statistics for isokinetic trunk strength, dynamic balance, and single-legged hop distance were presented in Table 1.

Table 1. Test results for the measurements

Measurements (n= 29)	Mean (SD)
Isokinetic trunk flexion (Nm/kg)	0.95 (0.16)
Isokinetic trunk extension (Nm/kg)	3.23 (0.99)
Anterior Balance (cm/leg length)	0.72 (0.10)
Posteromedial Balance (cm/leg length)	1.02 (0.15)
Posterolateral Balance (cm/leg length)	0.95 (0.16)
Single - legged hop distance (cm/leg length)	1.07 (0.22)

SD: standard deviation; Nm: Newtonmeter; kg: kilogram; cm: centimeter

The analysis revealed that SLHD was significantly associated with isokinetic trunk extension strength (r= 0.60, p= 0.001) and trunk flexion strength (r= 0.42, p= 0.024). Among dynamic balance measures, significant positive correlations were observed with posteromedial balance (r= 0.47, p= 0.002) and posterolateral balance (r=0.54, p=0.002). There was no correlation (r= 0.26, p= 0.17) between anterior balance and SLHD.

Linear regression results were provided in Table 2. A linear regression model was constructed to identify the best predictors of SLHD. Trunk extension strength (β= 0.504, p= 0.001) and posterolateral balance performance (β= 0.439, p= 0.003) emerged as significant predictors in the final model, which explained 54% of the variance in hop performance (R^2 = 0.54, p< 0.001).

DISCUSSION

This study examined the relationship between trunk strength, dynamic balance, and SLHD, a widely used functional performance test in rehabilitation and return-to-sport decision-making. The findings demonstrate that trunk extension strength and posterolateral dynamic balance are significant predictors of SLHD performance, together explaining more than half of its variance. These results highlight the critical role of proximal stability and multiplanar postural control in the functional performance of the lower limbs.

Table 2. Linear regression results (dependent variable: Single-legged for hop distance)

Variables	Coef	95% CI	β coef	P value
Isokinetic trunk extension (Nm/kg)	0.111	0.049 - 0.172	0.504	0.001
Posterolateral Balance (cm/leg length)	0.602	0.219 - 0.986	0.439	0.003

Constant value = 0.137, SLHD calculation = 0.137 + (0.111 Isokinetic Trunk Extension) (0.602Posterolateral Balance), coef: coefficient values; β coef: standardized coefficients; CI: confidence interval.

Trunk extension strength emerged as the most influential predictor of SLHD. This finding supports previous literature emphasizing the importance of the core, particularly the posterior musculature, in facilitating force transmission and dynamic postural control during single-limb tasks [22, 23]. Efficient trunk extension enables optimal alignment and energy transfer during both the propulsive and landing phases of hopping. It may also contribute to injury risk reduction by stabilizing the trunk and pelvis and preventing excessive trunk motion, which has been associated with increased knee joint loading and anterior cruciate ligament injury risk [23, 24]. These biomechanical mechanisms may explain the strong association between trunk extensor strength and SLHD in our participants.

Posterolateral balance also significantly contributed to SLHD performance, highlighting the importance of multiplanar neuromuscular control. The YBT, especially the posterolateral component, challenges frontal and transverse plane stability and requires integrated control from the trunk, pelvis, and lower limbs [25]. Prior studies have shown that deficits in dynamic balance are associated with reduced functional performance and increased injury risk [26, 27]. The observed relationship suggests that individuals with better control in the posterolateral direction may be more capable of managing the dynamic demands of single-legged propulsion and landing, which are essential components of the SLHD task.

While trunk flexion strength was moderately correlated with SLHD, it did not remain significant in the regression model. Trunk flexion may influence landing posture by encouraging a more flexed trunk position, which has been shown to reduce lower extremity stiffness and knee joint loads[9, 28]. However, this strategy may not directly enhance propulsion during the hop, which could explain why trunk extension strength was a more salient predictor. It is possible that trunk flexion strength supports injury prevention more than performance, while extension strength directly contributes to movement efficiency and power.

A strength of this study is its multidimensional assessment approach, incorporating both proximal (trunk) and distal (balance) factors to explain functional performance. Moreover, the use of normalized values enhances comparability across individuals. Nonetheless, several limitations should be considered. The cross-sectional design limits causal inference, and the modest sample size may reduce generalizability, especially to different populations such as elite athletes or clinical groups. Additionally, our sample consisted of healthy, young, recreationally active individuals, which may not reflect the characteristics of patients undergoing rehabilitation or return-to-sport testing. Future studies should explore longitudinal effects of trunk and balance training on SLHD and other functional performance measures.

CONCLUSION

Our findings underscore the importance of trunk extension strength and posterolateral balance in SLHD performance. These results suggest that clinicians and practitioners should integrate trunk strengthening and multidirectional balance exercises into rehabilitation and conditioning programs. Enhancing proximal stability and dynamic postural control may not only improve performance but also contribute to safer and more efficient return-to-sport pathways.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Kırşehir Ahi Evran University Clinical Research Ethics Committee, Kırşehir, Türkiye (Decision no: 2025-06/75, Date: 25/03/2025).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

The authors received no financial support for the research and/or publication of this article.

Author Contributions / Yazar Katkıları

Concept: BT, AT; design: BT, AT; supervision: BT, AT; materials: BT, AT, FT; data collection and/or processing: BT, SK, AT; analysis and interpretation: AT; literature review: BT, SK; writing manuscript: BT; critical reviews: BT, SK, FT, AT. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

REFERENCES

1. Dingenen B, Truijen J, Bellemans J, Gokeler A. Test-retest reliability and discriminative ability of forward, medial and rotational single-leg hop tests. *Knee.* 2019;26(5):978-87.
2. Wellsandt E, Axe MJ, Snyder-Mackler L. Poor performance on single-legged hop tests associated with development of posttraumatic knee osteoarthritis after anterior cruciate ligament injury. *Orthop J Sports Med*. 2018;6(11):232596711881077.
3. Guild P, Lininger MR, Warren M. The association between the single leg hop test and lower-extremity injuries in female athletes: a critically appraised topic. *J Sport Rehabil*. 2021;30(2):320-6.
4. Tayfur B, Johnson AK, Palmieri-Smith R. Changes in quadriceps rate of torque development after anterior cruciate ligament reconstruction and association to single-leg hop distance. *Sports Health*. 2023;19417381231205295.

5. Pua YH, Mentiplay BF, Clark RA, Ho JY. Associations among quadriceps strength and rate of torque development 6 weeks post anterior cruciate ligament reconstruction and future hop and vertical jump performance: a prospective cohort study. *J Orthop Sports Phys Ther.* 2017;47(11):845-52.
6. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train.* 2012;47(3):339-57.
7. Teng HL, Powers CM. Influence of trunk posture on lower extremity energetics during running. *Med Sci Sports Exerc*. 2015;47(3):625-30.
8. Kluger D, Major MJ, Fatone S, Gard SA. The effect of trunk flexion on lower-limb kinetics of able-bodied gait. *Hum Mov Sci.* 2014;33:395-403.
9. Tayfur A, Haque A, Salles JI, Malliaras P, Screen H, Morrissey D. Are landing patterns in jumping athletes associated with patellar tendinopathy? A systematic review with evidence gap map and meta-analysis. *Sports Med*. 2022;1-15.
10. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med*. 2007;35(7):1123-30.
11. Dominguez-Navarro F, Casaña J, Perez-Dominguez B, Ricart-Luna B, Cotolí-Suárez P, Calatayud J. Dynamic balance and explosive strength appears to better explain single leg hop test results among young elite female basketball athletes. *Sci Rep.* 2023;13(1):5476.
12. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. *Am J Sports Med*. 2009;37(5):890-7.
13. Demirkapı E, Ercan S, Başkurt F, Çetin C. Evaluation of activity score and kinesiophobia at anterior cruciate ligament reconstruction. *Süleyman Demirel Üniversitesi Sağlık Bilimleri Dergisi.* 2016;6(3):116-20.
14. Swearingen J, Lawrence E, Stevens J, Jackson C, Waggy C, Davis DS. Correlation of single leg vertical jump, single leg hop for distance, and single leg hop for time. *Phys Ther Sport.* 2011;12(4):194-8.
15. Alshehre Y, Alkhathami K, Brizzolara K, Weber M, Wang-Price S. Reliability and validity of the Y-balance test in young adults with chronic low back pain. *Int J Sports Phys Ther.* 2021;16(3):628.
16. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the Star Excursion Balance Test. *N Am J Sports Phys Ther.* 2009;4(2):92.
17. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012;47(3):339-57.
18. Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the Star Excursion Balance Test. *Arch Phys Med Rehabil*. 2008;89(2):364-70.
19. Hancı E, Atalay E, Şekir U, Akova B, Gür H. İzometrik ve izokinetik bel kuvvet ölçümlerinde Cybex Norm dinamometrenin güvenilirliği. Spor Hekimliği Dergisi. 2012;47(2):039-47
20. Granacher U, Lacroix A, Roettger K, Gollhofer A, Muehlbauer T. Relationships between trunk muscle strength, spinal mobility, and balance performance in older adults. *J Aging Phys Act*. 2014;22(4):490-8.
21. Shahtahmassebi B, Hebert JJ, Hecimovich MD, Fairchild TJ. Associations between trunk muscle morphology, strength and function in older adults. *Scientific Reports*. 2017;7(1):10907.
22. Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc*. 2004;36(6):926-34.
23. Zazulak BT. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med*. 2007;35:1123-30.
24. Hewett TE, Myer GD, Ford KR, Heidt RS, Colosimo AJ, McLean SG, et al. Neuromuscular control and valgus loading of the knee predict ACL injury risk in female athletes. *Med Sci Sports Exerc*. 2004;36:505-14.
25. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther.* 2006;36(12):911-9.
26. Butler RJ, Lehr ME, Fink ML, Kiesel KB, Plisky PJ. Dynamic balance performance and noncontact lower extremity injury in college football players: an initial study. *Sports Health*. 2013;5(5):417-22.
27. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes. *J Orthop Sports Phys Ther.* 2010;40(9):551-8.
28. Blackburn JT, Padua DA. Influence of trunk flexion on hip and knee joint kinematics during a controlled drop landing. *Clin Biomech*. 2008;23(3):313-9.