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Research Article

ARM AND LEG DOMINANCE DOES NOT AFFECT FUNCTIONAL BALANCE TESTS

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ABSTRACT

Objective: Functional balance tests are frequently used to evaluate individuals' balance, monitor rehabilitation outcomes, and determine fall risk. Motor tasks requiring strength and accuracy are performed with the dominant extremities. Therefore, there is a possibility that limb dominance may affect functional balance tests. The literature has no consensus on whether the dominant leg affects balance tests. To our knowledge, there is no study for the dominant arm. The purpose of this study is to investigate whether the dominant leg affects the one-leg standing test (OLST) and tandem stance test (TST), while the dominant arm affects the functional reach test (FRT).

Materials and Methods: One hundred healthy young adults were included in this prospective cross-sectional study. Participants' age, height, and weight were noted, and their body mass index (BMI) was calculated. Participants underwent OLST and TST on the dominant and non-dominant legs. FRT was applied with the dominant and non-dominant arms.

Results: While 93 (93.0%) of the participants were right extremity dominant, 7 (7.0%) were left extremity dominant. There was no difference in terms of OLST, and TST performed with the dominant and non-dominant leg (p>0.05). There was no difference in terms of FRT applied with the dominant and non-dominant arms (p>0.05).

Conclusion: Our study revealed that leg dominance did not affect OLST and TST, and arm dominance did not affect FRT. The extremity for applying OLST, TST, and FRT can be left to participant preference or applied based on the dominant/non-dominant extremity as appropriate to the situation.

Keywords: Balance, motor dominance, postural control, functional balance, arm

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INTRODUCTION

Balance and coordination facilitate maintaining posture, performing daily activities such as walking and running, and executing fine motor movements. Sensor and motor functions must work optimally to ensure balance and coordination (1). While sensory functions refer to vestibular, proprioceptive and visual inputs, motor function refers to corrective neuromuscular responses to maintain the centre of gravity vertically on the base of support (2). Impairments in one or more of these functions or impaired coordination between them reduce the quality of life and increase the risk of falls and hospitalization.
Sensory balance systems function in an organized and coordinated manner. The vestibulo-ocular reflex (VOR), which connects the vestibular and visual systems, stabilizes retinal images during head movements (3). For normal VOR gain, eye velocity should be equal to or closely matched with head velocity during head movements. The vestibulo-spinal reflex (VSR), on the other hand, connects the vestibular and proprioceptive systems (4). VSR plays a crucial role in maintaining posture against gravity and regulating muscle activity. In cases of abnormal VSR input, postural control weakens, balance disorders emerge, and coordination impairments may be observed.

Many complex systems, such as computerized dynamic posturography and biodex balance systems, are used to evaluate balance (5). However, accessing these systems is quite difficult and using these devices requires expertise. Balance and falls are interdisciplinary conditions that concern many branches, such as otorhinolaryngology, emergency medicine, neurosurgery and physical therapy. Therefore, functional balance tests are still frequently used to evaluate individuals' balance, monitor rehabilitation outcomes, and determine fall risk. Another advantage of these tests is that static, semi-static and dynamic balance can be quickly evaluated, and the tests can be modified. One-leg standing test (OLST), one of the static tests in which proprioceptive input is reduced, can be applied with eyes open and closed or on hard and soft ground, depending on the appropriate condition. Functional reach test (FRT), one of the semi-static tests, can be applied sitting or standing in the frontal and lateral planes (6). A timed up and go test is frequently preferred to evaluate dynamic balance in single and dual-task conditions.

Functional balance tests, while primarily assessing the coordination between balance systems and postural control, also provide valuable insights into the vestibular system through the VSR. On a firm and stable support surface in a well-lit environment, healthy individuals rely on the somatosensory system (70%), the visual system (10%), and the vestibular system (20%) (7). However, when the support surface becomes unstable or visual input is obstructed, reliance on vestibular information increases (7). Therefore, modified balance tests conducted with eyes closed or on a soft surface are crucial for evaluating vestibular system function.

Although the human body is anatomically symmetrical, one of the bilateral organs tends to be dominant. This phenomenon is explained by the concept of cerebral lateralization, which refers to the asymmetric distribution of specific functions between the two hemispheres of the brain. Accordingly, morphological and functional differences in the brain hemispheres determine which side of the body exhibits dominance. Studies have suggested that environmental factors such as birth stress, maternal age at delivery, the season of birth, fetal testosterone levels, and fetal position in the womb play a significant role in shaping cerebral lateralization (8-12). On the other hand, some studies indicate that cerebral lateralization is already present by the 15th week of intrauterine development (11). Therefore, genetic factors are thought to play a predominant role in the formation of cerebral lateralization (12).

Motor tasks requiring strength and accuracy are performed with the dominant (or preferred) extremities. Dominant extremities are often used when conducting tests in case leg or arm dominance affects functional balance tests. However, some individuals may have orthopaedic disorders in their dominant extremities and can perform the tests with the non-dominant extremities. Therefore, knowing how dominant and non-dominant extremities affect functional balance scores is important. However, in the studies in the literature, there is no consensus on whether the dominant leg affects balance tests (13). To our knowledge, there is no study for the dominant arm.

The purpose of this study is to investigate whether the dominant leg affects the OLST and tandem stance test TST), while the dominant arm affects the FRT.

MATERIALS AND METHODS

GPower 3.1 software was used to calculate the sample size. With an effect size of 1.046431, a power of 95%, and a significance level of 0.05, a minimum total sample size of 42 was required for the study (14).

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One hundred healthy young adults were included in this prospective cross-sectional study. Written and verbal consent was obtained from the participants. In addition, permission was received from the ethics committee of Karabük University (Decision no: 2023/5). To determine the dominant extremity, individuals were asked which hand they preferred when writing and which foot they used when kicking the ball. In addition, height and weight information were noted, and body mass index (BMI) was calculated. Participants underwent OLST and TST on dominant and non-dominant legs. FRT was applied with dominant and non-dominant arms. Considering the possibility of getting tired, participants were given a one-minute rest period between each test. In addition, since participants' motivation/attention may affect the tests, the testing of 50 individuals was started with the dominant extremity and the testing of 50 individuals was started with the non-dominant extremity. A simple randomization method determined which individual would start the test with the dominant and which with the non-dominant limb. The study did not include individuals with systemic, neurological, or orthopaedic disorders, symptoms such as dizziness/vertigo, and individuals who do professional sports.

One leg standing test

Participants were asked to take off their shoes, fold their arms across their bodies, and lift one leg (dominant or non-dominant). Individuals were asked to stand in this position for 30 seconds, and the time they could stand was recorded with a stopwatch. The test was repeated on hard and soft ground, with eyes open and closed, and with the other leg. The stopwatch was stopped when the individual lost balance, raised his arms, moved his foot to maintain his balance, or opened his eyes.

Tandem stance test

Participants were asked to take off their shoes and place the toe of one foot touching the heel of the other. Like OLST, the time individuals could stand in the desired position was noted. The test was repeated with both the dominant and non-dominant legs, respectively.

Functional reaching test

A tape measure was placed on the wall, and a line was drawn at the start and end points of the tape measure. Participants were asked to stand parallel to the wall and flex the arm on the wall side to 90 degrees (parallel to the tape measure). The participant was asked to lie forward. The distance the individual could reach forward was calculated. The test was repeated with both dominant and non-dominant arms respectively.

Statistical analysis

IBM SPSS 21 software was used for statistical analysis. The significance level was accepted as 0.05. Balance scores between dominant and non-dominant extremities were evaluated with the T-test when the data were normally distributed and with the Mann Whitney-U test when the data were not normally distributed. The relationship between age, height, weight, and balance tests was evaluated using the Spearman correlation test.

RESULTS

Eighty-four (84%) of the participants were female, 16 (16%) were male, and the average age was 20.32±3.40 (18-44). While 93 (93%) participants were right extremity dominant, 7 (7%) were left extremity dominant.

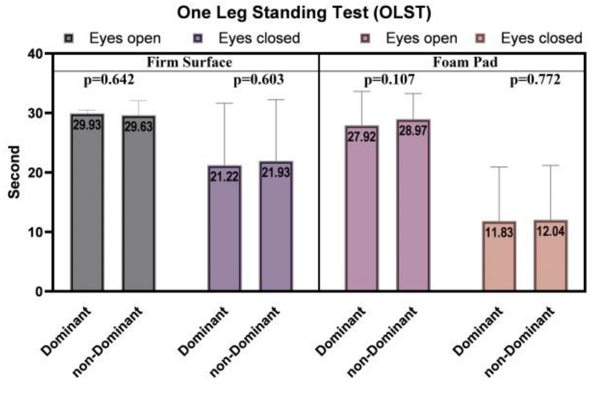

Figure 1. One Leg Standing Test for dominant and non-dominant legs.

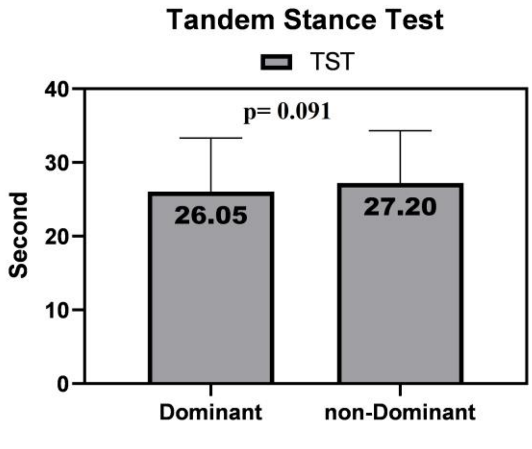

Figure 2. Tandem Stance Test for dominant and non-dominant legs.

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There was no difference in terms of OLST performed with the dominant and non-dominant leg (p>0.05, Figure 1). There was no difference in terms of TST performed with the dominant and non-dominant leg (p>0.05, Figure 2). There was no difference in terms of FRT applied with the dominant and non-dominant arms (p>0.05, Figure 3).

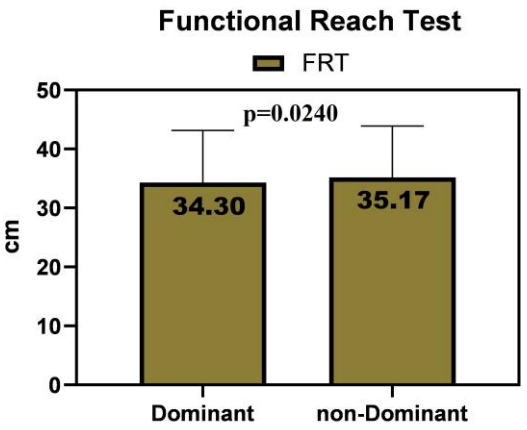

Figure 3. Functional Reach Test according to dominant and non-dominant leg.

There was a relationship between BMI and firm surface eyes closed OLST (Figure 4A), height and FRT and TST (Figure 4B), weight and FRT (Figure 4C), and age and firm surface eyes closed OLST (Figure 4D) (p<0.05).

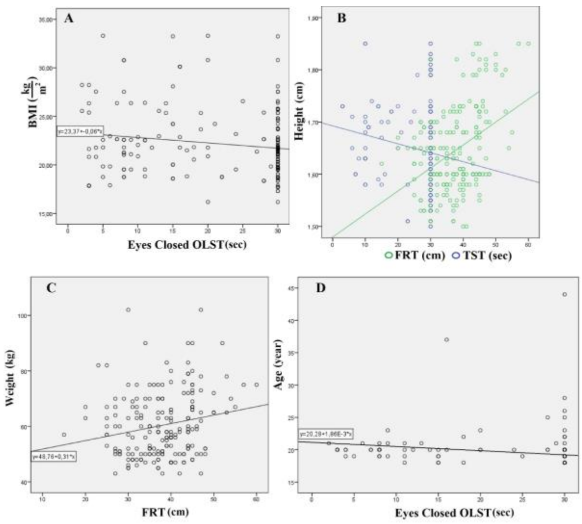

Figure 4. A: Relationship between BMI and firm surface eyes closed OLST. B: Relationship between height and FRT and TST. C: Relationship between weight and FRT. D: Relationship between and age and firm surface eyes closed OLST.

The relationship between age, height, weight, BMI and functional balance tests is presented in Table 1.

Table 1. Relationship between age, height, weight, BMI and functional balance tests (N=200).

		Age	Weight	Height	BMI
	Mean±Sd	**20.32±3.40**	**60.38±11.61**	**164.69±8.16**	**22.18±3.46**
		Correlation coefficient (p value)			
OLST, Firm Surface, second					
Eyes Open	29.93±0.49	-0.11 (.271)	-0.08 (.256)	-0.02 (.732)	-0.08 (.221)
Eyes Closed	21.22±10.42	-0.25 (.011)	-0.08 (.240)	0.07 (.274)	-0.15 (.026)
OLST, Foam Pad, second					
Eyes Open	27.92±5.70	-0.00 (.927)	-0.06 (.387)	0.07 (.315)	-0.04 (.494)
Eyes Closed	11.83±9.09	-0.12 (.263)	-0.02 (.769)	0.09 (.200)	-0.09 (.191)
TST, second	26.05±7.26	-0.10 (.294)	-0.04 (.521)	-0.18 (.009)	0.06 (.356)
FRT, cm	37.34±7.94	-0.04 (.689)	0.19 (.005)	0.35 (<.001)	-0.02 (.730)

Spearman Correlation test, OLST: One Leg Standing Test, TST: Tandem Stance Test, FRT: Functional Reach Test

DISCUSSION

This study aimed to determine whether arm and leg dominance affects OLST, TST and FRT. Our study determined that leg dominance did not affect OLST and TST, and arm dominance did not affect FRT.

The VSR is connected to the upper cervical region (medial tract) and lower extremities (lateral tract). Functional balance tests, in which we investigate arm and leg dominance, mainly evaluate the lateral VSR. The lateral VSR primarily extends to the ipsilateral spinal cord and modulates the α and γ motor neurons of the intraspinal pathways and lower extremity muscles (15). It stimulates lower extensor motor neurons and suppresses flexor motor neurons. In other words, it ensures an upright posture against gravity and plays an important role in maintaining balance by controlling muscle activity. OLST and TST are similar in terms of application. In both, surface area and proprioceptive input are reduced. Thus, confidence in the vestibular system increases. When performed with eyes closed, the visual system is also disabled, and the test becomes even more difficult. However, the main difference between the OLST and TST tests is the force exerted on the muscle and skeletal system. In TST, the body weight is shared on each leg, while in OLST, all the force is on one leg. For this reason, OLST is more susceptible to being affected by muscle strength. It has been reported in the literature that there are differences between dominant and non-dominant leg muscle strength (hamstring and quadriceps) (16). The main difference is that the flexor muscles are weak in the dominant leg while the extensor muscles are strong. Considering that the functional balance tests we applied constitute knee extension, it is expected that there may be a performance difference between the dominant and non-dominant legs due to the difference in strength. However, the findings of studies in the literature vary (14,17,18) Mala et al. (17) categorized football players according to age groups and investigated the effect of leg dominance on postural stability (PS). The authors reported that leg dominance did not affect PS. Muehlbauer et al. (18) performed OLST on 30 healthy young adults with dominant and non-dominant legs in 3 different situations (eyes open/firm ground, eyes open/foam ground and eyes closed/firm ground). The authors stated that leg dominance does not affect OLST and that both legs can be used during OLST. Another study (14) evaluated the stabilometric analysis of leg dominance using the OLST in athletes (football (n = 20), basketball (n = 20), windsurfing (n = 20)) and sedentary individuals (n = 20). The authors reported that football players exhibited better balance on the non-dominant leg. However, they found no significant difference in OLST performance between legs in the other athletes. This situation was explained by the fact that football players did a lot of training and that this training improved their non-dominant leg balance. The findings in the literature generally show no difference between balance tests performed on the dominant and non-dominant legs. The better performance of football players on the non-dominant leg during the OLST test is likely due to intense exercise, which leads the non-dominant leg to surpass the dominant leg. In other words, while there is no impact of leg dominance on balance performance in individuals with normal daily activities, training the non-dominant leg in football players gives it an advantage in terms of balance. We included young adults in our study, which was similar to Muehlbauer's study. The participants were not doing professional sports but performing daily activities. In our study, there was no difference in terms of OLST and TST between dominant and non-dominant legs. In other words, dominant and non-dominant legs can be used interchangeably in standard OLST and TST tests.

On the other hand, maintaining posture, balance, and activities such as walking in daily life requires continuity. Therefore, muscle fatigue can affect these functional abilities. Simoneau et al. (19) reported that muscle fatigue negatively impacts balance skills and that individuals compensate for this balance loss by allocating a greater proportion of cognitive resources to the active control of the balance task. Muscle fatigue also affects the dominant and non-dominant legs differently. Increased reliance on the dominant leg and prolonged exposure to high forces lead to excessive loading of the muscle-tendon components in this leg compared to the non-dominant leg (20). In our study, we did not assess participants' baseline fatigue levels. Additionally, we provided a one-minute rest period between tests and legs. Therefore, our findings do not simulate daily life but rather reflect results obtained in a laboratory setting. Future studies could investigate how muscle fatigue influences balance tests performed with the dominant and non-dominant legs. Moreover, the impact of limb dominance on motor performance in dual-task scenarios that simulate daily life would be crucial in understanding the real-world effects of leg dominance.

Our study also detected a negative relationship between BMI and eyes closed-firm surface OLST. Individuals with higher BMI spend more effort maintaining their balance in OLST. Therefore, leg muscles get tired faster. Thus, the negative relationship between BMI and eyes closed-firm surface OLST shows that fatigue can affect balance and investigating leg dominance in tired muscles will clarify the results. The lack of a relationship between BMI and other foam surface OLST can be explained by the emergence of different factors (such as vestibular abilities) that disrupt balance in the foam surface.

Ageing affects muscle mass. Muscle mass decreases by approximately 3-8% per decade after age 30 (21,22). The age range of the participants in our study was between 18-44. Although all participants were young adults, there was a negative relationship between age and eyes closed-firm surface OLST. This shows that the loss of muscle mass after the age of 30 affects OLST. For this reason, age should be considered when preparing normative data for OLST, and if possible, OLST results should be interpreted in decades.

FRT is designed to measure the maximum distance a person's arm length can reach forward while maintaining a stable base of support in the foot, that is, to evaluate the individual's anteroposterior stability (23). The test can be easily administered with a simple tape measure, and individuals' semi-dynamic balance skills can be evaluated validly and accurately. Studies in the literature generally state that FRT should be applied with the dominant arm (24). Although there are studies investigating different modifications of FRT in the literature (25), to the best of our knowledge, there is no study investigating the effect of arm dominance on FRT. Karabulut et al. (25) applied FRT on the firm and foam surface with the dominant and double arms. The authors reported that the most appropriate version to evaluate postural control is the firm surface of both arms FRT. Differently, we investigated the effect of arm dominance on FRT. Our study showed that arm dominance does not affect FRT. That is, in cases such as inappropriate room conditions or unilateral upper limb amputation, FRT can be applied validly, reliably and accurately with the dominant or non-dominant arm.

By its nature, FRT is affected by upper body length. Therefore, height and FRT have a positive relationship (26). On the contrary, fat [excess weight] in the belly area will make it challenging to maintain the centre of gravity when reaching forward and negatively affect FRT performance. We detected a positive relationship between FRT and height, which is consistent with the literature. However, a positive relationship also existed between FRT and weight. This can be explained by the fact that weight increases as height increases. Similarly, the lack of a relationship between FRT and BMI confirms our hypothesis.

This study has some limitations. First, we included only healthy adult participants, with the majority of the sample consisting of females (84%). Therefore, these findings are specifically applicable to healthy adults, and the uneven gender distribution may not fully reflect potential differences between sexes. Another limitation is that we did not assess participants' baseline fatigue before testing. Additionally, participants were given a one-minute rest period between tests. Future studies could consider the effects of fatigue or implement longer rest intervals between tests to explore the impact of the dominant extremity on balance performance in different populations, such as individuals with various medical conditions, athletes, children, or older adults.

CONCLUSION

In addition to the afferent information coming from the sensory organs, the contribution of the musculoskeletal system is also of great importance in maintaining posture and balance. Our study revealed that leg dominance did not affect OLST and TST, and arm dominance did not affect FRT. The extremity for applying OLST, TST, and FRT can be left to participant preference or applied based on the dominant/non-dominant extremity as appropriate to the situation.

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Authorship contributions
Conception: ES - Design: ES, MC - Supervision: ES, MS- Data Collection and/or Processing: MC - Analysis and/or Interpretation: ES - Literature Review: ES, MC - Writing: ES,MC- Critical Review: ES.

Data availibity statement
Data avaiable upon request

Declaration of competing interest
The authors declare that there is no conflict of interest.

Ethics
Ethical approval was obtained for the study from the university's ethics commission (Decision no: 2023/5).

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