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Relationship between Functional and Laboratory Balance Assessment in Females with Patellofemoral Pain Syndrome

Samira Nafez[1], Tabassom Ghanavati[1], Mohammad Akbari[2], Noushin Khalilian-Ekrami[1], Zahra Salahzadeh[1]

[1] *Faculty of Rehabilitation, Tabriz University of Medical Sciences, Tabriz, Iran*
[2] *Faculty of Rehabilitation, Iran University of Medical Sciences, Tehran, Iran*

CORRESPONDING AUTHOR:
Zahra Salahzadeh
Faculty of Rehabilitation
Tabriz University of Medical Sciences
29 Bahman Boulevard
Tabriz, Iran
E-mail: salahzadeh@tbzmed.ac.ir

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SUMMARY

Background. Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal problems, especially in young females. Dynamic standing balance impairment is a risk factor for PFPS. Objective of this study is to investigate the relationship between functional and laboratory dynamic standing balance assessment in women with PFPS to determine the role of each test in PFPS balance assessment and achieve a comprehensive approach to balance deficit detection in these patients.

Methods. Forty-nine females participated (26 with PFPS and 23 without). The Y balance test (YBT) as a functional balance test, consisted of anterior, posteromedial, posterolateral, and composite balance scales, and the Biodex balance system (BBS) as a laboratory stability test, consisted of total, anteroposterior, mediolateral stability indices, have been used in both groups. Pearson correlation coefficient test was used to compute the relationship between laboratory and functional balance tests. Independent t-test was used for between-group balanced comparisons.

Results. In control group, two balance tests had moderate to good correlation (r^2 = -0.44 to -0.80, $p \leq 0.01$), but in experimental group, there was limited balance scales correlation (r^2 = -0.45 to -0.50, $p \leq 0.02$). Statistically significant difference was found between the study and control group in all balance scales ($p \leq 0.000$).

Conclusions. Females with PFPS had dynamic standing balance impairment. Low Correlation between YBT and BBS in the PFPS group indicated that these two tests might assess a different aspect of balance. Therefore, it is appropriate to use other tests to better identify the relationship.

KEY WORDS

Patellofemoral pain syndrome; postural balance; proprioception; postural control; equilibrium.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the common knee musculoskeletal disorders characterized by the presence of idiopathic retro patellar and/or prepatellar pain aggravated by the activity-increased patellofemoral joint stress such as stair climbing, squatting, running, jumping, and kneeling (1-4). PFPS is commonly observed in adolescents and young physically active populations and prevalence in the general population was reported as 22.7 annually and the chance of affection in females is 2.23 times more in males (5). This syndrome can limit functional performance and intensively affect the quality of life (6). Also, some studies showed balance impairments in PFPS (7-13), but the recent systematic review study indicated that there is a controversy between studies about balance deficits in these patients (14).

Dynamic balance is defined as the ability to do a task while maintaining a stable position (15) and is a basic need for

independent activities of daily living (16-18). It was one of the three most important gait-related intrinsic risk factors for PFPS development (19). Standing balance deficits often lead to an increase in the risk of falling and this can limit the activity of daily living (ADL) (20). The results of Yelvar *et al.* (20) research indicated that the risk of falling increases in people with PFPS. This can affect their ADL and limit their functions. So, the dynamic standing balance assessment is a necessity for good rehabilitation of this group of patients.

Gender is one of the factors that can affect postural stability (21, 22). Males and females with PFPS have differences in kinematics, strength, and neuromuscular activation during functional activities (23), so it is expected that the balance control of females and males with PFPS has differed. There is controversy in studies that evaluated dynamic balance in females with this syndrome. Some studies showed no balance deficit (24, 25), but others showed impairment in overall, sagittal, frontal, or both of this movement plan (7, 8, 10, 11, 13, 26). With this in mind, there are some functional and laboratory dynamic standing balance assessment tests for these patients. The Y Balance Test (YBT) is a functional tool for lower limb balance evaluation derived from the star excursion balance test (SEBT) (27). It is a cost-effective and portable test to evaluate lower extremity dynamic balance and neuromuscular control and its reliability is very good (28). The Biodex Balance System (Biodex, Inc., Shirley, NY) (BBS) is one of the laboratory balance measure tools. It is a multiaxial device with a circular platform that can simultaneously move in the anterior-posterior and medial-lateral directions and calculate 3 stability indexes including anterior-posterior stability index (APSI), mediolateral stability index (MLSI), and overall stability index (OSI) (29, 30). It has moderate to good reliability in PFPS subjects (31). The BBS provides quick, objective balance assessment, but the device is costly so its use in clinical practice is limited (27). Nakagawa *et al.* evaluated the relationship between static, dynamic, and functional balance tests in people with a recurrent ankle sprain and found a very weak relationship between these tests in these patients (32). On the other hand, Akbari *et al.* examine the correlation between BBS and SEBT in athletes with an ankle sprain and found a good correlation (33).

Balance problems affect ADL and can decrease quality of life, so assessment of balance is very important. When both the YBT as a functional test and BBS as a laboratory test are used to evaluate dynamic balance in females with PFPS but no study investigated their relationship and their advantage as means for obtaining reliable feedback on this group dynamic balance and evaluating the effects of rehabilitation for them. So, this study aimed to investigate the relationship between functional and laboratory dynamic standing balance assessment in women with PFPS to determine the role of each test in PFPS balance assessment to achieve a comprehensive approach to balance deficit detection in these patients.

MATERIALS AND METHODS

The protocol of this study was approved by the ethics committee on research of Tabriz University of Medical Science (IRTBZMED.REC.1397.302 – Date of approval: July 21, 2018). All participants provided written informed consent before participation in this study.

Participants

The case-control study consisted of forty-nine females who were divided into two groups: the PFPS (either unilateral or bilateral) group (n = 26) and a matched control group (n = 23). Subjects with PFPS were diagnosed by an orthopedist and referred to a biomechanics laboratory according to inclusion and exclusion criteria. All tests were performed in the biomechanics laboratory of the Iran University of Medical Science. The subjects of the control group were recruited from Iran University of Medical Science students and personnel. The inclusion criteria for the PFPS group were non-athletic females aged 18-35 years with a history of unilateral or bilateral anterior knee pain of more than 3 months (10), the intensity of knee pain at least 3 of 10 according to visual analog scale (VAS) (11), pain in palpating medial or lateral facet of the patella (10), having pain during at least 3 of following activities: squatting, jumping, running, kneeling, standing when squatting, stair climbing, prolonged sitting, doing resistance exercises (10). The inclusion criteria for the control group were non-athletic females aged 18-35 years with no history of knee pain in any of the activities described for the PFPS group. The exclusion criteria for both groups were body mass index (BMI) more than 28 kg/m^2 (10), history of knee surgery, ligamentous and/or meniscus injuries (10, 13), patellar tendinopathy (10, 13), traumatic patellar dislocation (10, 13), ankle, hip, or lumbar joint injuries (10, 13), a neurological disorder (10, 13), use of anti-inflammatory medication (10, 13), pregnancy (10), increase subjects pain and conditions that effect on balance such as positional vertigo, hypertension, internal ear problems (13), not corrected eyesight problems (13), and if subjects did not want to continue participation in the investigation. The required sample size was calculated with a pilot.

Procedures

The control group was assessed by a physical therapist with 4 years of clinical experience to verify inclusion and exclusion criteria. The dominant limb was characterized by the kick-a-ball method (34). Then the lower limb length for each subject was measured in a supine position from the vertex of the anterior superior iliac spine to the center of the ipsilateral medial malleolus with a standard meter (35).

Balance tests

YBT

YBT is a version of SEBT that utilizes only three directions of eight directions of SEBT. This test consists of 3 tapes set in anterior (ant), posteromedial (post-med), and postero-lateral (post-lat) directions that form a "Y" shape together (36). Before this test, each person was educated by examiner instructions and with pictures about performing the test. Each participant stood in the center of the modified SEBT grid while her hands were on the hips barefoot and the most distal aspect of the greater toe of her test limbs was in the center (36). She wanted to reach as far as possible with her other limb in ant, post-med, and post-lat directions respectively while not weight bearing on reaching limb (36, 37). Participants did 6 practical trials (38) and 3 testing trials for each of the 3 reach directions. For each testing trial, the examiner visually recorded the location of the most distal part of the reaching foot as it contacts the grid in centimeters. The most recorded reach distance was used in future analyses. The test was repeated if (28, 36) the participant could not maintain a single leg stance throughout the test, the hands separated from hips during the test, the heel of the stance foot separated from the floor during the test, through reaching in any direction, the weight of the subject migrated from stance limb to reaching limb (the reaching limb contacted with the floor), if the subject was unable to return reaching limb to start position.

Biodex balance system

BBS (Biodex Medical Systems, Shirley, NY, USA) measures three stability indices: APSI, MLSI, and OSI (29, 34). The stability of the platform can be adjusted between 1 to 12 where level 1 is the most unstable and level 12 is the most stable level. In this study, we used level 6 for balance assessment. Before testing, the examiner instructed the participant about performing the test and each subject used the device for 1 minute to justify it (39). The participants were asked to single leg stance on the platform barefoot while the tested limb was on the platform and the other limb was in slight abduction and flexion of the hip and 90-degree flexion of knee position, they looked ahead, and their hand crossed the chest then were asked to adjust their foot and try to keep the platform in a horizontal position (9). The subjects preferred foot position was saved and was maintained for each one during the testing trial (18, 40). For testing, participants wanted to keep the platform as motionless as possible for 20 seconds without a change in head, hands, and lower limb position (41). Balance testing consisted of 2 practical and 2 testing trials (29). With 2-minute rest between practical and testing trials and 20 seconds rest between 2 testing trials. The average of 2 testing trials was recorded and used for future analysis. The test was repeated if the position of the head, hands, and lower limbs changed during the test, the subject was unable to maintain a single leg stance or complete the determined time for balance test (20 s) throughout the test.

Statistical analysis

Spss 16 software was used for data analysis. The level for statistical significance value was set to $p < 0.05$. The normality of the data distribution was determined with the Kolmogorov-Smirnov test. Comparison between PFPS and control group balance indices was performed by independent t-test. All data had normal distribution, so the Pearson correlation coefficient was used to distinguish the strength of correlation between YBT and BBS balance scales with a coefficient value set as follows: 0-0.19 = none to slight; 0.20-0.39 = low; 0.40-0.69 = moderate; 0.70-0.89 = high, and 0.90-1 = very high (42).

RESULTS

There was no significant difference in demographic characteristics between the PFPS and control groups ($p < 0.05$, **table I**).

Balance assessment

Table II shows the means and standard deviation (SD) of the BBS and YBT balance scales. Analysis by independent t-test showed significant differences between PFPS and control groups for all balance indices of YBT and BBS ($p < 0.01$, **table II**).

Correlation analysis

In the correlation analysis of the PFPS group, we found only some low to moderate indirect correlations come in follow: BBS OSI and YBT anterior $r = -0.45$, $p < 0.05$; right BBS APSI and right YBT anterior $r = -0.50$, $p < 0.05$, **table III**). In the control group, we found moderate to strong indirect correlation in all balance scales of two tests ($r = -0.44$ to -0.80 and $p < 0.01$, **table IV**).

Table I. Demographic features of study participants.

Demographic data	PFPS group (n = 26) Mean (SD)	Control group (n = 23) Mean (SD)	P-value (mean difference)
Age (year)	23.27 ± 4.10	23.22 ± 3.71	0.96
Height (m)	1.65 ± 0.05	1.65 ± 0.04	0.06
Mass (kg)	59.85 ± 8.03	61.91 ± 5.31	0.30
BMI (kg/m^2)	22.83 ± 2.40	22.70 ± 1.58	0.82
Lower limb length (cm)	83.25 ± 5.23	85.63 ± 4.04	0.08

PFPS: patellofemoral pain syndrome; SD: standard deviation; BMI: body mass index.

Table II. Comparison between YBT and BBS balance indices (mean ± SD).

Balance indices	PFPS group	Control group	P-value
YBT overall (%)	72.75 ± 4.70	85.09 ± 2.92	0.000
YBT anterior (%)	64.76 ± 3.32	76.42 ± 3.18	0.000
YBT posteromedial (%)	80.03 ± 6.35	91.80 ± 4.70	0.000
YBT posterolateral (%)	73.49 ± 6.64	87.08 ± 4.19	0.000
BBS OSI (Degree)	1.73 ± 0.52	0.54 ± 0.16	0.000
BBS APSI (Degree)	1.48 ± 0.54	0.35 ± 0.12	0.000
BBS MLSI (Degree)	0.56 ± 0.28	0.32 ± 0.14	0.000

Table III. Correlation between YBT and BBS balance indices in the PFPS group.

Test	BBS OSI		BBS APSI		BBS MLSI	
	R^2	P-value	R^2	P-value	R^2	P-value
YBT overall	-0.17	0.38	-0.18	0.35	0.02	0.90
YBT anterior	-0.45*	0.02	-0.50**	0.009	-0.01	0.90
YBT posteromedial	0.06	0.70	0.07	0.73	0.003	0.98
YBT posterolateral	-0.22	0.27	-0.22	0.27	0.04	0.81

R^2 values and P-values for the correlation analysis between the Y balance test (YBT) and biodex balance system (BBS) balance scales in the patellofemoral pain syndrome (PFPS) group; a significant correlation is indicated with the asterisk ($p < 0.05$).

Table IV. Correlation between YBT and BBS balance indices in the control group.

Test	BBS OSI		BBS APSI		BBS MLSI	
	R2	P-value	R2	P-value	R2	P-value
YBT overall	-0.73**	0.000	-0.73**	0.000	-0.52**	0.003
YBT anterior	-0.80**	0.000	-0.80**	0.000	-0.53**	0.002
YBT posteromedial	-0.66**	0.000	-0.66**	0.000	-0.44*	0.01
YBT posterolateral	-0.59**	0.001	-0.59**	0.001	-0.47**	0.008

R^2 values and P-values for the correlation analysis between the Y balance test (YBT) and biodex balance system (BBS) balance scales in the control group; a significant correlation is indicated with the asterisk ($p < 0.05$).

DISCUSSION

Our result showed also the females with PFPS had standing balance deficits in all balance scales of both laboratory and functional tests but the relationship between these two tests was weak in these groups of patients.

BBS balance evaluation

The result showed all BBS balance scales are significantly greater in PFPS. Since a greater balance scale in BBS indicates poor balance (9), dynamic standing balance control was impaired in females with PFPS. Several parameters can

affect standing balance control in PFPS including proprioception deficits (43-46), impairment in ankle, knee, and hip joints kinematic and muscle performance (7-11, 47, 48), pain (12, 20, 49), and deficit in core stability (20, 50). These findings are consistence with previous studies that examine the PFPS group dynamic standing balance with BBS (13, 51). But on the other hand, there was some controversy between this study's results and previous ones (9, 12). Negahban *et al*. (9) evaluated the dynamic standing balance in people with PFPS and found only an anterior-posterior (sagittal plane) balance deficit and there was no significant difference in overall and medial-lateral balance scales between this group of patients and the control. This inconsistency can be because of the difference in demographic features of participants of these two studies. Negahban *et al*.'s research was on both males and females, but gender effect on kinematic and balance control (21, 44), so in the present study just females joined. The other reason can be the different methodologies of the two studies. Negahban *et al*. used level 4 of BBS and we used level 6. Balance control in level 4 is more difficult than 6, so it can challenge the control group's balance and their overall and medial-lateral balance scales may be decreased so they couldn't find differences in these balance scales. Rezazadeh *et al*. (12) measured the dynamic standing balance of athletes men with PFPS and in open eyes conditions, just the overall balance scale was different compared to the control group. This controversy in our study can be because of differences in the demographic features of participants. Being male and an athlete can increase the balance of these patients so the researchers couldn't find differences in other balance scales.

YBT balance evaluation

Our findings showed all YBT balance scales of females with PFPS are lower than control ones. A lower balance scale in YBT means poor balance control, so the females with PFPS had poor balance control in all directions of YBT. These results are in agreement with previous studies (26, 44, 52, 53). But there was some dissimilarity between Song and Zamboti's research (24, 25). Song *et al.* (24) measured the balance of females with PFPS by anterior direction of YBT and didn't find any difference compared to controls. This disagreement can be because of the methodological difference between the two studies. Song *et al*. used only 4 practical tests before the main test which could be not enough to control the learning effect. On the other hand, in contrast to our study, in their study, the distal point of the mover limb had touched the ground. The other reason can be the participants' number that was 16 in Song *et al*. which was lower than ours. Zamboti *et al*. (25) in another study evaluated the balance of 10 women with PFPS by three directions of YBT and found no difference compared to controls. The controversy of this research to ours can be because the participant's number was very lower than in our study.

Correlation of BBS and YBT

The result of this investigation showed only some low to the moderate indirect correlation between BBS and YBT balance scales in the PFPS group, but this relationship was moderate to high in almost all balance scales of the two tests in the control group. The lack of correlation between BBS and YBT in females with PFPS can indicate that each test has different balance aspects in this group. Balance controlling is a complex performance including three basic aspects: 1) maintaining the body position, 2) controlling the stability in conscious movement, 3) appropriate response to external perturbation (54), and needs the integration of sensory information, central processing, and motor response (39). In the present study, YBT can maintain stability in a conscious movement, but BBS has the ability of postural control toward an external perturbation that is the movable platform. So, each of these tests may have different aspects of balance that can be complemented or one be weaker in balance evaluation than another (32, 54-56) that needs further investigation. On the other hand, YBT is a functional test that needs lower limb coordination, flexibility, muscle strength, and balance (52). It seems that this test has the overall joint performance more than a specific balance test (32). The exact balance properties described by functional balance evaluation can't be defined easily because other factors than balance affect this test performance (56). These results are consistent with previous studies (32, 56). Nakagawa *et al*. (32) investigated the relationship between functional and laboratory balance tests in people with a recurrent ankle sprain and found a very weak association. Sawacha *et al*. (56) have the correlation between functional balance tests and posturography in chronic hemiplegic post-stroke persons and found only some relationships. In contrast to our study, Zamboti *et al*. (25) found a moderate correlation between YBT overall balance scale and static unimodal COP oscillation measured by force plate in females with PFPS. This disagreement can be because of methodological differences between the two studies. They investigated the correlation between static COP and YBT, but we determined the association between two dynamic balance tests. The good correlation in the control group indicated the fact that all aspects of balance controlling are appropriate in this group, so the acceptable association was expectative. This good correlation in the control group wasn't consistent with previous ones (27, 57). The previous study didn't separate the males and females. It seems that gender has a significant effect on balance control as demonstrated in other studies (21, 58, 59).

This study had some limitations: we didn't determine the pain level and functional capacity. Perhaps the person with different levels of pain and functional capacity had a different balance controlling. We didn't determine the factors that could affect each test such as proprioception and muscle strength, etc. Further investigations are needed to research these factors. The same study in the male group with PFPS should be performed.

Limitation and future perspectives

This study had some limitations. Only the females with PFPS were included in the study so due to the influence of gender in maintaining balance and kinematic differences and muscle strength between women and men, it is suggested to measure the relationship between functional and laboratory dynamic standing balance in the males with PFPS. In this study the patients with the history of knee pain during the last 3 months has been participated. It seems that the results of function and balance tests are different in patients with chronic anterior knee pain and maybe this issue could influence the relationship between functional and laboratory balance tests. Therefore, it is suggested to investigate this relationship in patients with chronic PFPS.

CONCLUSIONS

Females with PFPS had a dynamic standing balance deficit. Both YBT as a functional test and BBS as a laboratory test showed this deficit but the correlation between the two tests in this group of patients was weak. So, it needs to perform a similar study with different functional and laboratory balance tests to better identify the relationships.

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None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

SN, TG, ZS: design. SN, MA: data collection. ZS, TG: data analysis. SN, ZS, NKE: writing - original draft. TG, MA: writing - review & editing.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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