Dynamic Knee Alignment and Pelvic Balance: Comparison Regarding Gender in Young Soccer Athletes*

Alinhamento dinâmico do joelho e equilíbrio pélvico: Comparação entre os sexos em atletas de futebol de base

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Rev Bras Ortop 2021;56(2):175–180.

Abstract

Objective To evaluate knee alignment in the frontal plane and pelvic balance during the step-down test in female and male soccer players.
Methods Cross-sectional study carried out with male and female soccer players from under-15 and under-17 teams of a professional club in Southern Brazil. The step-down test was performed, filmed with a video camera, and evaluated according to the angular measurements obtained during movement using the Kinovea software (open source), version 0.8.24.
Results The sample consisted of 38 individuals, 19 males and 19 females. Female athletes had a greater varus angle ($9.42° \pm 1.65°$) compared to male athletes ($3.91° \pm 2.0°$; $p = 0.04$). There was no difference regarding the unilateral pelvic drop between the groups. In addition, the association between the hip-related pelvic drop and the projection angle on the frontal plane of the knee was weak in both genders.
Conclusion Even though the pelvic drop was observed in both genders, young female athletes had greater varus knee angles on the step-down test, which require greater attention to minimize the risk of injury.

Keywords
► soccer
► genu valgum
► genu varum
► pelvis

Resumo

Objetivo Avaliar o alinhamento do joelho no plano frontal e o equilíbrio pélvico durante a descida de um degrau comparando atletas de futebol feminino e masculino.
Métodos Estudo transversal, realizado com atletas de futebol das categorias sub-15 e sub-17, de ambos os sexos, de um clube profissional do Sul do Brasil. Foi realizado o teste de descida de um degrau, o qual foi filmado por uma câmera de vídeo, e, em sua

* *Study developed at Universidade Católica de Pelotas, Pelotas, Rio Grande do Sul, Brazil.*

received September 11, 2019
accepted September 16, 2020

DOI https://doi.org/10.1055/s-0040-1721361.
ISSN 0102-3616.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

avaliação, traçaram-se as medidas angulares durante o movimento por meio do software Kinovea (código aberto), versão 0.8.24.

Resultados A amostra foi composta por 38 indivíduos, 19 do sexo masculino e 19 do sexo feminino. As atletas do sexo feminino apresentaram maior ângulo em varo ($9,42° \pm 1,65°$) quando comparadas com os atletas masculinos ($3,91° \pm 2,0°$; $p = 0,04$). Não houve diferença em relação à queda unilateral da pelve (*drop* pélvico) entre os grupos, e a associação entre o *drop* pélvico do quadril e o ângulo de projeção no plano frontal do joelho foi fraca em ambos os sexos.

Conclusão Apesar de ambos os sexos terem apresentado queda pélvica, as atletas de base do sexo feminino apresentaram maior angulação do joelho em varo no teste de descida do degrau, e necessitam maior atenção para minimizar o risco de lesão.

Palavras-chave
- futebol
- genu valgum
- genu varum
- pelve

Introduction

At a high performance level, soccer is a physically complex, intense sport that may cause injuries, especially in the lower limbs.[1] A number of factors are related to non-contact injuries, including age, gender, body morphology, muscle strength, flexibility, and joint stability and alignment[2] Among the changes in dynamic joint alignment, the valgus or varus knee is associated with the highest risk of injury, since misaligned lower limbs increase the load imposed on the joint. As such, health professionals must identify and minimize this risk factors in soccer athletes.[3,4]

Excessive valgus during running subjects the knee to chronic tension on medial ligament structures, and results in an abnormal rigidity in the iliotibial tract; in contrast, the varus increases the load imposed on the lateral ligament complex of the knee.[5] The kinematics of the lower limbs is directly related to the pelvic girdle, and the weakening of the pelvic muscles, such as the abductors and external rotators of the hip, in addition to the delayed activation time of the hip musculature, can reflect in a dynamic knee misalignment.[6–8] Studies show that subjects with weakened pelvic muscles are more likely to develop patellofemoral pain;[9,10] in addition, the dynamic misalignment of the knee is related to more serious injuries which prevent athletic activities for long periods of time, such as injuries to the ankle ligament and rupture of the anterior cruciate ligament of the knee.[11–13]

Even though there is a trend to generalize pelvic muscle weakness in lower-limb injuries, other factors, including gender, must be considered.[14] More specifically, among athletes at the same level of activity, women are more susceptible to sports injuries, presenting them in a higher incidence and greater severity. This occurs because women have lower general stability and muscle strength, in addition to joint hypermobility resulting from hormonal factors, which can potentiate a biomechanical change during movement.[11,12,15–17] Women present increased angle of adduction and medial hip rotation due to weakness of the abductor and lateral hip rotator muscles; this fact led to the hypothesis that female athletes have greater dynamic misalignment of the knee and less movement control when compared to the male athletes since adolescence. Therefore, women require more attention regarding the risk of new injuries.[16]

As such, the present study aims to compare the relationship between knee alignment in the frontal plane and pelvic balance during the step-down test in young female and male soccer players.

Materials and Methods

Participants

The present is a cross-sectional study with young athletes from a professional soccer club in Southern Brazil. The study was approved by the Research Ethics Committee of Universidade Católica de Pelotas (opinion report number: 1.759.216), and the participants and their guardians respectively signed a consent form for underage participants and an informed consent form. The sample was selected per convenience, and all athletes from the club's youth ranks (under-17 and under-15), of both genders, were invited to participate in the study. The inclusion criterion consisted of playing soccer for the team during the season. The exclusion criteria were defined as the following: athletes submitted to lower-limb surgery within the previous 6 months, those absent due to injury during data collection, those who felt pain during test, athletes with discrepancy in the lower limbs, and those unable to perform the test without exacerbated postural compensations.

At the initial approach, 68 informed consent forms were retrieved; however, 22 athletes did not return to contact, and were considered lost. Another eight athletes were excluded from the study: one for having dropped out during the test, three due to knee pain, and four because they were unable to perform the step-down movement without exaggerated postural compensations. These last four subjects presented excessive trunk flexion that completely covered the markers positioned on the hip, increasing the chance of analytical error. As such, the final sample consisted of 38 athletes, 19 male and 19 female athletes.

Procedures

Investigators were previously trained and qualified regarding the location and demarcation of the landmarks for analysis. A pilot study was carried out with two volunteers for the adaptation of the method. All demarcations and software-based measurements were performed by a single evaluator to sustain the standardization of thr criteria.

Discrepancy and pain in the lower limbs

Lower-limb discrepancy was evaluated with the athletes in the supine position. Two points were marked, one on the anterosuperior iliac spine, and the other on the medial malleolus. A difference $\geq$ 1 cm between the limbs was considered a positive test. Pain was assessed withthea visual analog scale (VAS), which ranges from 0 to 10, with 0 indicating no pain, and 10, extreme pain.[18]

Pelvic drop and knee dynamic alignment

The unilateral pelvic drop and the frontal plane projection angle (FPPA) of the knee were evaluated during the step-down test by video recordings in 2D with a camera (AFC 183 14 megapixels, Kodak, Rochester, NY, US) 2 meters away from the athlete, fixed to a tripod at a height of 60 cm. For a better evaluation of the recordings, landmarks, including the anterosuperior iliac spines, the midpoint between the femoral epicondyles, and the midpoint between the malleoli, were identified with non-reflective adhesives.[7] The Kinovea software (open source), version 0.8.24, was used for the angular analysis of the in-motion data. The unilateral pelvic drop was defined by the inferior displacement of one of the hip demarcations, contralateral to the examined limb; it often results from weakness of the gluteus medius muscle of the supporting limb (►**Figure 1**); valgus misalignment was defined as the medial displacement of the knee marker (negative angular values in relation to the midline), whereas varus misalignment was determined by a lateral increase in the distal markers (positive angular values in relation to the midline) (►**Figure 2**).

The height of the step was standardized as 16 cm. The athletes were instructed to remain 15 cm away from the step. Subsequently, they were asked to climb on the step and remain as relaxed as possible for 10 seconds to capture a frontal image at the beginning of the test; next, they were asked to step down, touching the heel on the ground 5 cm in front of the step, on previously-made markings. Before the test, the athletes performed three rounds of rehearsal for adaptation; the mean values of the five consecutive tests were considered for analysis. The supporting limb was assessed during the movement.[6]

Statistical Analysis

The angles were analyzed using the Kinovea software, and the values are presented as means and standard deviations. The Shapiro-Wilk test was performed to verify data distribution. The Student *t*-test for independent samples was used for the comparative analysis of the mean pelvic drop and mean FPPA in athletes from both genders; the level of significance was set at 5%. The Pearson correlation was used to analyze the association between the pelvic drop and the FPPA. The r-value was interpreted as follows: r = 0 to 0.19, no association; 0.2 to 0.39, low association; 0.4 to 0.69, moderate association; 0.7 to 0.89, high association; and 0.9 to 1.0, strong association. All statistical analyses were performed using the STATA (StataCorp, College Station, TX, US) software, version 12.2.

Fig. 1 Evaluation of the pelvic drop using the step-down test in young soccer players (Kinovea software, version 0.8.24).

Fig. 2 Evaluation of the frontal plane projection angle(FPPA) of the knee using the step-down test in young soccer players (Kinovea software, version 0.8.24).

Results

The characteristics of the sample are presented in ►**Table 1**. There was a disparity between the male and female athletes regarding the time of soccer practice, and it must be highlighted that 89.5% of men had been playing for 5 years or more, compared to only 5.3% of women.

►**Table 2** compares the mean pelvic drop and mean FPPA in female and male athletes submitted to the step-down test. Although there is no significant difference regarding the pelvic drop, female athletes present, on average, a greater varus angle on the step-down test ($p = 0.04$).

►**Table 3** shows that the association between the pelvic drop and the varus angle of the knee is weak in both genders; as such, this is not the main factor for joint misalignment in our sample of young athletes.

Discussion

The main finding of the present study was that young female soccer athletes had lower knee alignment in the frontal plane

Table 1 Characteristics of the sample of young soccer players

	Gender	Under-15	Under-17	Total
Mean (standard deviation) age (in years)	Male	15 (0.00)	16.6 (0.51)	16.4 (0.69)
	Female	14.5 (1.07)	17 (0.00)	15.9 (1.43)
Time of practice				
Less than 1 year	Male	0%	0%	0%
	Female	50%	27.3%	36.8%
1 year	Male	0%	5.9%	5.25%
	Female	12.5%	18.2%	15.8%
2 years	Male	0%	0%	0%
	Female	25%	36.3%	31.6%
3 years	Male	0%	5.9%	5.25%
	Female	12.5%	9.1%	10.5%
5 years or more	Male	100%	88.2%	89.5%
	Female	0%	9.1%	5.3%
Guided soccer practice				
Once a week	Male	0%	0%	0%
	Female	37.5%	18.2%	26.3%
3 times a week	Male	50%	35.3%	36.8%
	Female	50%	54.5%	52.6%
More than 3 times a week	Male	50%	64.7%	63.2%
	Female	12.5%	27.3%	21.1%

Table 2 Comparison of the knee FPPA and pelvic drop using the step-down test in young soccer players

		Male			Female		
	N	Mean	Standard deviation	N	Mean	Standard deviation	*p*-value
FPPA (degrees)	19	3.91	2.00	19	9.42	1.65	0.04*
Pelvic drop (cm)	19	9.00	3.02	19	9.67	3.25	0.51

Abbreviation: FPPA, frontal plane projection angle.
Notes: Student *t*-test; *statistically-significant difference.

(varus deviation) during the step-down test. In addition, the pelvic drop was observed in both males and females, but it does not seem to be the main factor related to this misalignment.

Although pelvic muscle weakness is usually associated with dynamic valgus compensation, soccer athletes, like those in our sample, present a trend toward varus.[19] The varus is characterized by hip abduction and lateral rotation of the knee. Particularly in soccer, a change in the postural knee pattern to varus is common due to the greater use of hip abduction and flexion chains according to the specific sport movement.[7,20]

Our study dynamically evaluated the pelvic drop and frontal knee alignment of both male and female adolescent athletes using the step-down test. For weight-unloading activities in a closed kinetic chain, force results from a ground reaction medially to the knee joint, leading to a possible joint misalignment, which is resisted primarily by the collateral ligaments and adjoining musculature.[21] In fact, lower-limb misalignment occurs in sports,[22] and the female population apparently presents the greatest angular variations in the frontal plane due to lower joint stability and higher weakness in the pelvic girdle muscles.[9,23,24] However, other factors require further analysis.[7,25] In decelerating sport movements, women have lower knee flexion angles during the initial contact with the ground, because they

Table 3 Association between knee angle in the frontal plane and pelvic drop on the step-down test in young soccer players

	r-value*	*p*-value
Total (N = 38)	0.34	0.13
Male (N = 19)	0.31	0.19
Female (N = 19)	0.35	0.14

Note: *Pearson correlation.

present a biomechanical decrease in hip-flexion angles.[3] The muscles surrounding the hip joint play a key role in stabilization during movement, especially in the dynamic frontal knee alignment;[26] as such, weakened hip muscles can render women more susceptible to sports injuries, especially those with increased severity, including to the knee ligaments.[10,12,14,27,28]

Strengthening the trunk, pelvis and hip muscles can increase stability and decrease knee misalignment during the step-down test,[6] and this generally involves all lower-limb kinematics.[29,30] In addition to muscle strength, a greater range of motion also appears to be important. A study with 39 young female soccer players showed an inverse correlation between the range of motion of the hip and knee alignment, that is, a lower range of motion of the hip is associated with greater frontal misalignment;[20] pelvic girdle stability seems more complex than the mere analysis of its drop during movement.

In addition for a greater control of the pelvic and trunk muscles, programs and instructions for the control of knee alignment during movement can decrease pain and improve functional performance, especially in women.[10] In a study[31] carried out with 22 athletes, women had a higher electromyographic activation of the quadriceps and lower activation of the maximum gluteus during single-leg landing when compared to men. Therefore, increased quadriceps activity combined to lower gluteal activity can contribute to the altered energy absorption during landing by overloading other lower-limb muscle groups and increasing the risk of injury.[31] Programs guided by trained professionals can increase the activation of specific muscles, improving the quadriceps–hamstring ratio and the function of the hip adductor and abductor muscles. These programs are important for joint stability and alignment, and they benefit soccer athletes, especially females.[17]

It is also worth mentioning that, in addition to gender-related physiological differences, that is, the greater dynamic knee misalignment in women due to the lower muscle strength, greater widening of the pelvis and increased ligament laxity, resulting in an increased susceptibility to sports injuries compared to men, it is logical that long-term training facilitates the proper execution of sport movements, saving energy and potentially protecting the athlete from injuries. Regarding teenage soccer, males often play for a longer time and with higher frequency; this is consistent with our findings, in which almost 90% of the male participants had been playing for more than 5 years, compared to only 5% of the female athletes. As such, clinical care and injury prevention must be potentialized in females since their teen years.

Although the present is a cross-sectional study, which may limit conclusions about the cause–effect relationship in knee alignment, we believe that it is essential that health professionals working with athletes are be able to identify dynamic misalignments and institute specific injury-prevention protocols starting at the youth ranks, with special attention to the female population due to their physiological and biomechanical predisposition to a higher incidence and severity of injuries.

Conclusion

Even though both genders presented a pelvic drop, young female athletes had greater varus knee angles on the step-down test, and require greater attention to minimize the risk of injury.

Conflict of Interests
The authors have no conflict of interests to declare.

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