DOI: 10.1590/1809-2950/16081424042017

ORIGINAL RESEARCH

Influence of menstrual cycle phases in functional performance of healthy and young women

Influência das fases do ciclo menstrual no desempenho funcional de mulheres jovens e saudáveis

Influencia de las fases del ciclo menstrual en el rendimiento funcional de mujeres jóvenes y sanas

Aline Tiemi Kami[1], Camila Borecki Vidigal[1], Christiane de Souza Guerino Macedo[2]

ABSTRACT | Female sex hormones as estrogen and progesterone are related to specific receptors located in brain regions and can influence on motor control. We analyzed the functional performance in several menstrual cycle phases in healthy and young women. The study is characterized as cross-sectional, it included 13 healthy women with regular menstrual cycle and who were not using oral contraceptive. To assess the functional performance, we used Side Hop Test (SHT), Figure of Eight Hop Test (F8T) and Modified Star Excursion Balance Test (mSEBT) applied in three phases of the menstrual cycle (menstrual, ovulation and luteal). This study established significant difference to functional tests SHT and F8T between menstrual cycle phases, with worse results for the menstrual phase. The mSEBT established no difference. We concluded that the functional performance in tests SHT and F8T was significantly worse on menstrual phase, when compared to the ovulation and luteal phases. These results can be considered for assessment and prescription of physical therapeutic conducts for women in menstrual phase, since their functional performance can be impaired.

Keywords | Menstrual Cycle; Motor Activity; Postural Balance; Proprioception; Physical Therapy.

RESUMO | Os hormônios sexuais femininos como estrogênio e progesterona têm relação com receptores específicos localizados em regiões cerebrais e podem influenciar o controle motor. Analisou-se o desempenho funcional nas diversas fases do ciclo menstrual em mulheres jovens e saudáveis. O estudo caracteriza-se como transversal e incluiu 13 mulheres saudáveis com ciclo menstrual regular e que não faziam uso de contraceptivo oral. Para a avaliação do desempenho funcional foram utilizados os testes *Side Hop Test* (SHT), *Figure of Eight Hop Test* (F8T) e *Modified Star Excursion Balance Test* (mSEBT) aplicados em três fases do ciclo menstrual (menstrual, ovulatória e lútea). Este estudo estabeleceu diferença significativa para os testes funcionais SHT e F8T entre as fases do ciclo menstrual, com piores resultados para a fase menstrual. O mSEBT não estabeleceu qualquer diferença. Concluiu-se que o desempenho funcional nos testes SHT e F8T foi significativamente pior na fase menstrual, quando comparado à ovulatória e lútea. Estes resultados podem ser considerados para avaliação e prescrição de condutas fisioterapêuticas para mulheres na fase menstrual, já que seu desempenho funcional pode estar comprometido.

Descritores | Ciclo Menstrual; Atividade Motora; Equilíbrio Postural; Propriocepção; Fisioterapia.

RESUMEN | Las hormonas sexuales femeninas como estrógeno y progesterona tienen relación con receptores específicos localizados en regiones cerebrales y pueden influenciar el control motor. Se analizó el rendimiento funcional en las diversas fases del ciclo menstrual en mujeres jóvenes y sanas. El estudio se caracterizó como transversal e incluyó a 13 mujeres sanas con ciclo menstrual regular y que no utilizaban anticonceptivo

[1]Physical therapist, collaborator in Research Laboratory in Sport Physical Therapy (Lafesp – *Laboratório de Pesquisa em Fisioterapia Esportiva*) of the Universidade Estadual de Londrina (UEL) – Londrina (PR), Brazil.
[2]Doctor in Rehabilitation and Functional Performance, Faculty in the Department of Physical Therapy of the Universidade Estadual de Londrina (UEL), professor of Doctoral and Master's Program in Rehabilitation Sciences, associated with Universidade Estadual de Londrina/Univerisdade Norte do Paraná (UEL/Unopar), and coordinator in Research Laboratory in Sport Physical Therapy (Lafesp), Universidade Estadual de Londrina (UEL) – Londrina (PR), Brazil.

Corresponding address: Professor Dra. Christiane de Souza Guerino Macedo – Av. Robert Koch, 60, – Londrina (PR), Brazil – Zip Code: 86038-350 – E-mail: chmacedouel@yahoo.com.br – Phone: (43) 3371-2490 – Finance cource: Nothing to declare – Conflict of interests: Nothing to declare – Presentation: 3 Oct. 2016 – Accepted for publication: 21 Nov. 2017 – Approved by the Research Ethics Committee with Human Subjects of Universidade Estadual de Londrina under Protocol No. 492.604/2013.

oral. Para la evaluación del rendimiento funcional se utilizaron las pruebas *Side Hop Test* (SHT), *Figur e of Eight Hop Test* (F8T) y *Modified Star Excursion Balance Test* (mSEBT) aplicados en tres fases del ciclo menstrual (menstrual, ovulatoria y lútea). Este estudio estableció una diferencia significativa para las pruebas funcionales SHT y F8T entre las fases del ciclo menstrual, con peores resultados para la fase menstrual. El mSEBT no estableció ninguna diferencia. Se concluyó que el desempeño funcional en las pruebas SHT y F8T ha sido significativamente peor en la fase menstrual comparándose a la ovulatoria y lútea. Estos resultados pueden ser considerados para evaluación y prescripción de conductas fisioterapéuticas para mujeres en la fase menstrual, ya que su rendimiento funcional puede estar comprometido.

Palabras clave | Ciclo Menstrual; Actividad Motora; Equilibrio Postural; Propiocepción; Fisioterapia.

INTRODUCTION

In the course of the menstrual cycle (MC), the levels of sex hormones, estrogen and progesterone, show a dynamic regulation. We know that during the beginning of MC there are low levels of estrogen and progesterone; and that in the late follicular phase, in the next ovulation, there is a peak in estrogen levels, followed by another peak in estrogen and progesterone in the middle of luteal phase[1,2].

Over the last years, variations of these female sex hormones have been the subject of many studies. In this sense, the literature reports that the female physiology seems to be affected by cyclical hormonal changes arising from the menstrual cycle; in which estrogen and progesterone, in addition to the regulation of reproductive function, show actions on the central nervous system (CNS). Studies show that these sex hormones may influence on neurotransmitters such as GABA, serotonin, and glutamate, acting on membrane receptors[1-3], being able to influence different brain regions with alteration of sensory perception and motor responses[4-9].

In addition, we suggest that estrogen and progesterone influence on physiological functions such as aerobic and anaerobic capacity, changes in soft tissues, muscular strength, proprioception, neuromuscular coordination and postural control[1,2,9-13]. For example, besides acting on the CNS, the estrogen also acts on the cellular level by decreasing the production of collagen in tendons by lessening the fibroblastic activity[7]. Dedrick et. al[8] explain that estrogen receptors are present in skeletal muscle, which can change the motor control and myofascial force transmission patterns. Constantini et al.[5] report that progesterone shows central thermogenic effect, which explains the increase in body temperature (from 0.3°C to 0.5°C) during the luteal phase (LP); and still during this phase, the hormone can improve the minute ventilation and response to maximum exercise. As for Fridén et al.[6], they point out that the increase in progesterone during luteal phase, metabolized in neurosteroids, such as *allopregnanolone* and *pregnanolone*, can explain balance and motor skill disorders in this phase due to the action over GABA-A receptors.

Functional performance tests are characterized as dynamic measures used to assess the general function of lower extremities[14,15,18]. Clinically, functional tests are often used in advanced stages of rehabilitation and as criterion for the return to sport[19,20]. Moreover, the importance in using functional tests results in the fact that the function of the lower extremities include many variables such as pain, edema, crepitation, neuromuscular and postural control, muscle strength, agility and joint stability; important aspects to perform a precise movement[15-19]. Examples of functional performance tests: Figure of Eight Hop Test (F8T), Side Hop Test (SHT) e Modified Star Excursion Balance Test (mSEBT).

Considering the possible influence of the menstrual cycle phases on motor skill and the existence of few studies that relate functional performance to the menstrual cycle, the aim of our study was to analyze the influence of functional performance of young and healthy women using functional tests in different MC phases. Our hypothesis is that the functional performance can be affected by the menstrual cycle phases in which the serum concentrations of estrogen and progesterone would be low.

METHODOLOGY

The research was conducted according to Resolution 466/12 of the National Health Council,

and approved by the Ethics Committee of the Universidade Estadual de Londrina (OPINION: 492.604/2013). All volunteers signed the Informed Consent Form. This study is characterized as cross-sectional, with sample recruited from the local university.

The convenience sample was established with 13 volunteers. It was considered as inclusion criteria: age between 18 and 35 years old; regular menstrual cycle (between 21-35 days[9]) in the last two months; and no use of any contraceptive agents. It was established as exclusion criteria: injury in the lower extremities (LE) in the last six months; presence of blisters or skin lesions on the feet; background of balance disorders, associated comorbidities and obesity. Thus, 20 volunteers were initially recruited. However, seven were excluded: three for injury on LE and four gave up during the study due to unavailability for reassessments, which resulted in a sample of thirteen (13) volunteers.

Procedures

Initially, all volunteers answered the characterization form of the sample with data on name, age, body mass, height, body mass index (BMI), dominance, in addition to background information on the menstrual cycle for the last two months (cycle length in days, pain symptoms), practice of physical activity (type and frequency), previous diseases, medication in use, including the use of contraceptive agents.

One of the problems when dealing with functional tests is the possible learning effect. Thus, all volunteers conducted a familiarization session, where they could practice the functional tests F8T, SHT and mSEBT until they felt secure and able to carry them out, to adaptation and reduction of learning effect[19,21].

Functional tests were conducted with the dominant (DLE) and non dominant (NDLE) lower extremity, at random. In the F8T[18], it was established the distance of five meters between two cones, one volunteer in single-limb stance should perform the route of "eight" format, in the shortest time possible. The SHT[18] demanded that volunteers performed ten lateral jumps, as soon as possible, at a distance of 30 cm demarcated by two lines on the ground. The time was timed and considered in seconds, for these two tests. The mSEBT was conducted in three directions: anterior (A), posterolateral (PL) and posteromedial (PM). In this test, volunteers should stand with the calcaneus on the intersection of the three tapes, with hands on waist, not allowed to move (raise or drag) the support foot from the ground, remove their hands from the waist or lose the balance in any form. As a result, it was considered the range of the lower extremity, in centimeters[23]. For mSEBT normalization, the length of the LE was evaluated. The measurement was conducted from the anterior superior iliac spine to the end of the medial malleolus[18,22]. The mSEBT score was calculated based on Filipa et al[25], where mSEBT=[(A+PM+PL)/(LEx3)x100].

The determination of the menstrual cycle phases was considered based on the study of Eiling et al.[26]. The length of each volunteers' MC was estimated using the average of the length of previous MC. Thus, the beginning of the next cycle could be estimated. Based on this information, the Ovulation Phase (OP) was determined by counting 14 regressive days from the estimated MC. The Luteal Phase (LP) was estimated by counting 7 days from the OP. And the Menstrual Phase (MP) was established on the day of menstruation. Thus, each volunteer was assessed in three phases, always starting from the menstrual phase, followed by follicular and luteal phases; and each woman had the specific day for the tests.

After familiarization session, the functional tests in MP were applied (between the 1st and 3rd days of the cycle, where low hormone levels are expected), with randomization of LE and for the sequence of performance of functional tests. The tests were conducted in three repetitions, with 30 seconds of interval between each repetition and between each test, in which the volunteer remained seated, at rest. The volunteers received verbal and visual instructions for each test.

After data collection on MP, the collections in OP were scheduled (14th day of the cycle, characterized by elevation in estrogen levels and low progesterone levels); and in LP (with progesterone and estrogen elevation, phase defined seven days after OP). The randomization of LE and the sequence of functional tests were performed again at each stage of analysis (Figure 1). In spite of the volunteers have showed menstrual regularity over the past two months, they were contacted again after the last collection to inform when the menstrual phase of the next MC had began, to confirm the regularity of the menstrual cycle assessed.

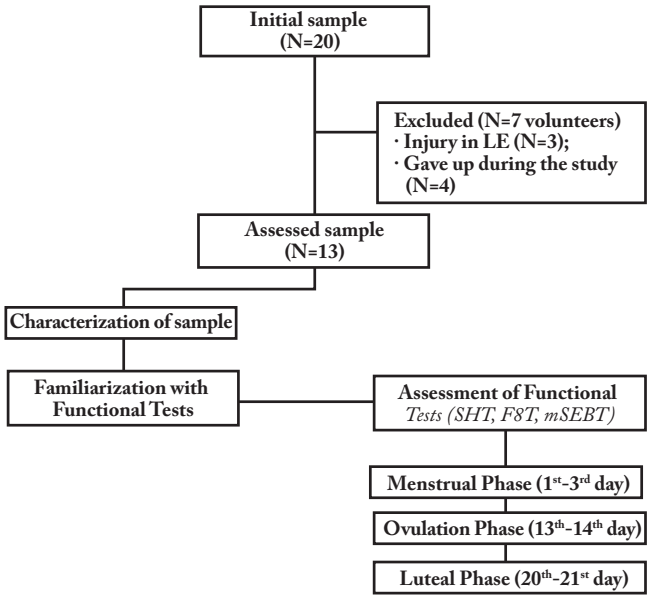

Figure 1. Flowchart of characterization to the stages of the study. LE: lower extremities. SHT: Side Hop Test. F8T: Figure of Eight Hop Test. mSEBT: Modified Star Excursion Balance Test

Statistical analysis

To compare the functional tests, the best result from the volunteers among the three attempts of each functional test and in each phase of the menstrual cycle was considered. For statistical analysis the software SPSS and GraphPad Prisma were used, with significance level at 5% ($p<0.05$). The normal distribution was established by the Shapiro-Wilk test. The Friedman Test and post Dunn's Test were used to compare the MC phases in the three functional tests.

RESULTS

The final sample had thirteen women that were healthy, nulliparous, with mean age of 21.31±2.59 years old, body mass at 58.15±9.83 Kg, height at 1.61±0.05 m, BMI at 22.48±3.49 Kg/m^2, MC length of 31.58±3.34 days; of these, five were sedentary, eight practitioners in gym and one futsal athlete, all with regular menstrual cycle between 21-35 days[9].

The performance results in tests SHT and F8T were significantly worse in the menstrual phase, when compared to the ovulation and luteal; but no difference was observed between the last two (ovulation and luteal), for both LE. The mSEBT pointed no difference between the three menstrual cycle phases (Table 1).

Table 1. Results of Functional Tests in menstrual cycle phases of young and health women (n=13)

Functional Test	Menstrual Median (min/max)	Ovulation Median (min/max)	Luteal Median (min/max)	Friedman Test
SHT				
DLE	4.9(3.75/10.85)	4.68(3.72/7.56)*	4.56(3.41/8.67)*	0.009
NDLW	5.35(4.06/10.28)	4.9(3.76/9.82)*	4.68(3.69/8.08)*	0.003
F8T				
DLE	13.33(9.86/15.84)	12.82(9.66/15.15)*	12.39(8.97/14.17)*	0.0004
NDLW	13.6(10.00/15.62)	12.5(9.21/14.75)*	12.44(9.50/14.06)*	0.002
mSEBT				
DLE	79.71(67.78/103.29)	82.25(73.33/95.88)	82.05(70.37/100.41)	0.295
NDLW	80.42(70.37/107.59)	80.9(68.75/103.38)	78.82(69.58/103.38)	0.600

* Significant difference when compared to the menstrual phase established through Friedman's test and post Dunn's test. SHT: Side Hop Test. F8T: Figure of Eight Hop Test. mSEBT: Modified Star Excursion Balance Test. DLE: dominant lower extremity NDLE: nondominant lower extremity

DISCUSSION

In this study, we examined the influence of the MC phases on the functional performance of 13 young and healthy volunteers through functional tests. As results, we point out that during MP the volunteers had worse functional performance in tests SHT and F8T. No statistical difference in dynamic balance was observed through mSEBT.

Functional tests have been used to assess components of sports performance (strength, power and agility), to determine the return to sports, evaluate the effectiveness of interventions for neuromuscular training and predict LE injuries[28]. Functional tests of single-limb hops, as SHT and F8T, evaluate motor functionality of individuals because they require postural and neuromuscular control[29], since they have lateral displacements components (SHT)[14,17], movements

that lead to rotational stress (F8T)[14,15], in addition to require quick changes of direction and cover physical components such as coordination and speed[17,18].

Our results showed performance differences in functional tests F8T and SHT in the three menstrual cycle phases. We consider that the estrogen can influence the neuromuscular performance, since the receptors of this hormone (alpha and beta) were identified in skeletal muscle, and that it also acts on the CNS, including upper motor centers[2-4,6].

The proprioceptive information derive from peripheral receptors in the joints, muscles and ligaments (such as Golgi tendon organ, free nerve endings, Pacinian corpuscle and Ruffini endings), and are conducted via dorsolateral tract, with important role in the control of muscle stiffness and joint dynamic stability[30]. Moreover, the somatosensory system is a complex sensory component of the neuromuscular system that covers the perception and execution of musculoskeletal control and movement[31].

Aydog et al.[27] investigated the MC effects on proprioception of 19 healthy women through the Join Position Sense Test (JPST), compared the menstrual phase (2nd-4th days), follicular phase (9th-11th) and luteal phase (16th-18th days), and established that proprioception had significant reduction during the menstrual phase, as a consequence of change in distal latency or on excitability of mechanoreceptors. However, in this study the measurement of serum of hormone levels was not used by blood or urine samples. Notwithstanding, the authors report that in spite of the participants being initially included by having regular MC in the last three months, the ones with irregularities in the MC to be assessed, such as delay of two days or anticipation of three days in menstruation were excluded.

As for Fridén et. al[2,] they evaluated the neuromuscular control of athlete women, through the Square test, on MP (between 3rd-5th days), OP (9th-11th days) and premenstrual phase (7 days after OP), and they observed no correlation between the number of jumps and hormone levels; however, the volunteers at OP had better performance when compared with premenstrual and menstrual phases.

Our results corroborated with data from literature[2,25,31] that low concentrations of estrogen can impair neuromuscular control during menstrual phase which implies worse performance in functional tests during this phase.

In addition to the estrogen analysis, studies have shown that progesterone can modulate the function of glutamate and GABA receptors in the cerebellum, which would impairment of postural balance[1-3,6]. Fridén et. al[6] investigated the postural control through the platform of strength in women with and without premenstrual syndrome (PMS) in the: early follicular (3rd-5th days), ovulation (identification by LH) and luteal phases (7 days after ovulation). These authors concluded that there were decreases in postural control during the luteal phase in women with PMS, and observed a greater displacement of the oscillation center of pressure in anteroposterior direction. These findings are explained because LP is associated with high levels of progesterone, higher than in other phases; resulting in increase in its conversion rate in neurosteroids, with consequent change in balance and motor function[6].

In this study, mSEBT was used to assess the dynamic postural balance, a low cost and high applicability test, widely used in research and clinical practice, because it provides objective measurements to identify the deficits and improvements in postural control and dynamic balance. The mSEBT has been proved to be responsive to training programs in both affected patients and healthy participants[23]. However, in this study, the mSEBT showed no significant difference in dynamic balance between MC phases.

This study had limitations that should be considered. Our sample had sedentary volunteers, practitioners of gym and athlete, with different levels of physical conditions, previous training and possible muscle memory to perform exercises. Another limitation refers to accuracy of the beginning and end of each MC phase. In this study, blood samples and measurements of serum of sex hormones were not used, which are considered another standard to these analyses, and would increase the strength of the results. We suggest that future studies may use more precise measurements of hormone levels in different MC phases for a better understanding and guidance of the findings. Finally, our study conducted no prior training for functional tests used, which may have influenced on their performance. However, as a way to minimize this effect and, as suggested by Bolgla, Keskuda[19] and Robinson, Gribble[21], a prior practice and familiarization with the tests were provided to the participants, as well as randomization to the order of beginning of tests on each assessment.

Nonetheless, we believe that the worst functional performance results in menstrual phase can be considered for developments of prevention programs, training and neuromuscular rehabilitation of young and healthy women, with adaptations of exercises and training. Moreover, the functional tests used have low cost and are easy and simple to apply, which allows their reproduction on any location, either for interventions or assessment in physical therapy.

CONCLUSION

The results of this study indicate that the functional performance of healthy and young women was influenced by the different phases of the menstrual cycle, with worse results in the menstrual phase for the tests SHT and FH8, and the consequent impairment of coordination and speed to achieve them. However, the dynamic balance, assessed through the *mSEBT*, pointed no changes regarding the menstrual cycle phases.

REFERENCES

1. Darlington CL, Ross A, King J, Smith PF. Menstrual cycle effects on postural stability but not optokinetic function. Neurosci Lett. 2001;307(3):14-50. doi: 10.1016/S0304-3940(01)01933-4
2. Friden C, Hirschberg AL, Saartok T, Renstrom P. Knee joint kinaesthesia and neuromuscular coordination during three phases of the menstrual cycle in moderately active women. Knee Surg Sports Traumatol Arthrosc. 2006;14(4):383-9. doi: 10.1007/s00167-005-0663-4
3. Friden C, Hirschberg AL, Saartok T, Backstrom T, Leanderson J, Renstrom P. The influence of premenstrual symptoms on postural balance and kinesthesia during the menstrual cycle. Gynecol Endocrinol. 2003;17(6):433-9. doi 10.1080/09513590312331290358
4. Smith MJ, Adams LF, Schmidt PJ, Rubinow DR, Wassermann EM. Effects of ovarian hormones on human cortical excitability. Ann Neurol. 2002;51(5):599-603. doi: 10.1002/ana.10180
5. Constantini NW, Dubnov G, Lebrun CM. The menstrual cycle and sport performance. Clin Sports Med. 2005;24(2):51-82. doi: 10.1016/j.csm.2005.01.003
6. Friden C, Ramsey DK, Backstrom T, Benoit DL, Saartok T, Hirschberg AL. Altered postural control during the luteal phase in women with premenstrual symptoms. Neuroendocrinology. 2005;81:150-7. doi: 10.1159/000086592
7. Bryant AL, Crossley KM, Bartold S, Hohmann E, Clark RA. Estrogen-induced effects on the neuro-mechanics of hopping in humans. Eur J Appl Physiol, 2011;111(2):245-52. doi: 10.1007/s00421-010-1647-8
8. Dedrick GS, Sizer PS, Merkle JN, Hounshell TR, Robert-McComb JJ, Sawyer SF, et al. Effect of sex hormones on neuromuscular control patterns during landing. J Electromyogr Kinesiol. 2008;18(1):68-78. doi: 10.1016/j.jelekin.2006.09.004
9. Barbosa MB, Montebelo MIL, Guirro ECO. Determinação dos limiares de percepção sensorial e de resposta motora nas diferentes fases do ciclo menstrual. Rev Bras Fisioter. 2007;11(6):443-9. doi: 10.1590/S1413-35552007000600005
10. Janse de Jonge XAK, Boot CRL, Thom JM, Ruell PA, Thompson MW. The influence of menstrual cycle phase on skeletal muscle contractile characteristics in humans. J Physiol. 2001;530(1):161-6. doi: 10.1111/j.1469-7793.2001.0161m.x
11. Caudhari AMW, Lindenfeld TN, Andriacchi TP, Hewett TE, Riccobene J, Myer GD, et al. Knee and hip loading patterns at different phases in the menstrual cycle: implications for the gender difference in anterior cruciate ligament injury rates. Am J Sports Med. 2007;35(5):793-800. doi: 10.1177/0363546506297537
12. Montgomery MM, Shultz SJ. Isometric knee-extension and knee-flexion torque production during early follicular and postovulatory phases in recreationally active women. J Athletic Training. 2010;5(6):586-93. doi: 10.4085/1062-6050-45.6.586
13. Fouladi R, Rajabi R, Naseri N, Pourkazemi F, Geranmayeh M. Menstrual cycle and knee joint position sense in healthy female athletes. Knee Surg Sports Traumatol Arthrosc. 2012;20(8):1647-52. doi: 10.1007/s00167-011-1811-7
14. Heleno LR, Silva RA, Shigaki L, Araújo CGA, Candido CRC, Okazaki VHA et. al. Five-week sensory motor training program improves functional performance and postural control in young male soccer players: a blind randomized clinical trial. Phys Ther Sport. 2016;22:74-80. doi: 10.1016/j.ptsp.2016.05.004
15. Suda EY, Souza RN. Análise da performance funcional em indivíduos com instabilidade do tornozelo: uma revisão sistemática da literatura. Rev Bras Med Esporte. 2009;15(3):233-7. doi: 10.1590/S1517-86922009000300014
16. Shigaki L, Rabello LM, Camargo MZ, Santos VBC, Gil AWO, Oliveira MR, et al. Análise comparativa do equilíbrio unipodal de atletas de ginástica rítmica. Rev Bras Med Esporte. 2013;19(2):104-7. doi: 10.1590/S1517-86922013000200006
17. Rabello LM, Macedo CSG, Oliveira MR, Fregueto JH, Camargo MZ, Lopes LD, et al. Relação entre testes funcionais e plataforma de força nas medidas de equilíbrio em atletas. Rev Bras Med Esporte. 2014;20(3):219-22. doi: 10.1590/1517-86922014200301720
18. Caffrey E, Docherty CL, Schrader J, Klossner J. The ability of 4 single-limb hopping tests to detect functional performance deficits in individuals with functional ankle instability. J Orthop Sports Phys Ther. 2009;39(11):799-806. doi: 10.2519/jospt.2009.3042

19. Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. J Orthop Sports Phys Ther. 1997;26(3):138-42. doi: 10.2519/jospt.1997.26.3.138

20. Docherty CL, Arnold BL; Gansneder BM, Hurwitz S, Gieck J. Functional-performance deficits in volunteers with functional ankle instability. J Athl Train. 2005;40(1):30-4.

21. 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. doi: 10.1016/j.apmr.2007.08.139

22. Abt JP, Sell TC, McCrory LJL, Loucks TM, Berga AL, Lephart SM. Neuromuscular and biomechanical characteristics do not vary across the menstrual cycle. Knee Surg Sports Traumatol Arthrosc. 2007;15(7):901-7. doi: 10.1007/s00167-007-0302-3

23. 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. doi: 10.4085/1062-6050-47.3.08

24. Coughlan GF, Fullam K, Delahunt E, Gissane C, Caulfield BM. A Comparison between performance on selected directions of the star excursion balance test and the y balance test. J Athl Train. 2012;47(4):366-71. doi: 10.4085/1062-6050-47.4.03

25. Filipa A, Byrner 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. doi: 10.2519/jospt.2010.3325

26. Eiling E, Bryant AL, Petersen W, Murphy A, Hohmann E. Effects of menstrual-cycle hormone fluctuations on musculotendinous stiffness and knee joint laxity. Knee Surg Sports Traumatol Arthrosc. 2007;15(2):126-32. doi: 10.1007/s00167-006-0143-5

27. Aydog ST, Hasçelik Z, Demirel HA, Tetik O, Aydog E, Doral MN. The effects of menstrual cycle on the knee joint position sense: preliminary study. Knee Surg Sports Traumatol Arthrosc. 2005;13(8):649-53. doi: 10.1007/s00167-004-0604-7

28. Smith J, DePhillipo N, Kimura I, Kocher M, Hetzler R. Prospective functional performance testing and relationship to lower extremity injury incidence in adolescent sports participants. Int J Sports Phys Ther. 2017;12(2):206-18.

29. Cronstrom A, Roos EM, Ageberg E. Association between sensory function and hop performance and self-reported outcomes in patients with anterior cruciate ligament injury. J Sports Med. 2017;8:1-8. doi: 10.2147/OAJSM.S120058

30. Demeritt KM, Shultz SJ, Docherty CL, Gansneder BM, Perrin DH. Chronic ankle instability does not affect lower extremity functional performance. J Athl Train. 2002; 37(4):507-11. PMC164385.

31. Naessen T, Lindmark B, Lagerstrom C, Larsen HC, Persson I. Early postmenopausal hormone therapy improves postural balance. Menopause. 2007;14(1):14-9. doi: 10.1097/01.gme.0000248707.53075.7f