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Effect of muscle fatigue on posture control in soccer players during the short-pass movement

Efeito da fadiga muscular sobre o controle postural durante o movimento do passe em atletas de futebol

Bruno Manfredini Baroni [1]
Matheus Joner Wiest [1]
Rafael Abeche Generosi [1]
Marco Aurélio Vaz [1]
Ernesto Cesar Pinto Leal Junior [2]

Abstract – Muscle fatigue is characterized by the inability to generate or maintain an expected effort or force level and negatively affects sports performance. One of the functional consequences of fatigue is a decrease in static and dynamic postural stability. The objective of this study was to evaluate the effect of muscle fatigue induced by high-intensity exercise on the dynamic postural stability of soccer players during the characteristic motor action of the sport: the short-pass. Twenty-seven male soccer players aged 14 to 16 years performed the short-pass movement on a stabilometric platform before and after a high-intensity exercise protocol performed on a cycle ergometer. After the fatigue protocol, the athletes presented a 31% increase in the mean velocity of the center of pressure displacement. Moreover, although the difference in the center of pressure displacement amplitude in the medial-lateral direction (15%) was not significant, displacement increased by 22% in the anterior-posterior direction. It was concluded that muscle fatigue promotes a decrease of postural stability during the short-pass movement in soccer players, probably compromising the sports performance of the athletes.

Key words: Muscle fatigue; Postural stability; Soccer; Sports performance.

Resumo – *A fadiga muscular é caracterizada pela incapacidade na geração ou manutenção de um nível de força, afetando negativamente o desempenho esportivo. Dentre as consequências funcionais da fadiga encontra-se o decréscimo do controle postural estático e dinâmico. O objetivo do estudo foi verificar o efeito da fadiga muscular induzida por exercício de alta intensidade sobre a estabilidade postural dinâmica de atletas de futebol, durante o gesto motor característico do esporte: o passe. Participaram do estudo 27 atletas de futebol do sexo masculino, entre 14 e 16 anos, que executaram o movimento do passe sobre uma plataforma estabilométrica antes e após a realização de um protocolo de exercício de intensidade máxima em ciclo-ergômetro. Após o protocolo de fadiga, os atletas apresentaram aumento de 31% na velocidade média de deslocamento do centro de pressão. Além disso, apesar de a diferença na amplitude de deslocamento do centro de pressão no sentido médio-lateral (15%) não ser significante, houve um significativo aumento de 22% no deslocamento ântero-posterior. Conclui-se que a fadiga muscular é capaz de promover decréscimo da estabilidade postural de jogadores de futebol durante o gesto motor do passe, o que provavelmente prejudica o desempenho esportivo dos atletas.*

Palavras-chave: *Desempenho esportivo; Equilíbrio postural;Fadiga muscular; Futebol.*

1 Federal University of Rio Grande do Sul. Laboratory of Exercise Research. Porto Alegre, RS. Brazil.

2 Nove de Julho University. Post Graduate Program in Rehabilitation Sciences. São Paulo, SP. Brazil.

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INTRODUCTION

The maintenance of static or dynamic postural balance depends on the ability of the central nervous system to interpret the information derived from the visual[1], vestibular[2] and somatosensory[3] systems, regulating muscle activity through reflex and voluntary responses[4]. Although balance assessment is complex, one of the techniques most widely used for the evaluation of the postural stability of an individual is stabilometric assessment, which a force platform fixed on the ground identifies the orientation and intensity of forces applied on the ground[5]. This objective and quantitative tool analyzes the ability to maintain postural stability through quantification of body oscillations. These body oscillations are measured by the displacement of the center of pressure (COP), which corresponds to the location point of the vertical ground reaction force vector and is related to the displacement responses at the center of gravity of the individual[5].

The integrity of postural stability during movement is a key factor for sports performance[6]. In addition, a decline in this capacity is a risk factor for a series of injuries[7,8]. Although posture control is a trainable quality[9], studies involving cyclists[10] and runners[11] have shown that this control is negatively affected by muscle fatigue. This complex and multifaceted biological phenomenon is usually associated with the inability to maintain a required or expected level of force, or even with the impossibility to continue exercising at a certain intensity[12]. However, these concepts should not convey the equivocal idea of the existence of an exact point during exercise when fatigue occurs, since there is a gradual decline in the capacity of maximum force production of a muscle until the inability to perform the motor task in question, a point commonly called "exhaustion"[13]. In addition to a reduction in the efficiency of the musculoskeletal system as a result of factors acting at the level of the central nervous system and intrinsic factors of the musculature, fatigue also compromises the function of the proprioceptive and exteroceptive sensory system, negatively affecting posture control[10,14].

Considered to be the most popular sport in the world, soccer has intermittent characteristics in which the performance of the athletes depends on physical, technical, tactical, and psychological factors[15]. Since soccer players run about 10-12 km over the 90 min of a game, performing a high-intensity run approximately every 70 s[16], it is normal for the players to show significant levels of fatigue, especially during the final periods of the game[7,17]. Although there is evidence indicating a reduction in kick performance as a result of muscle fatigue[18,19], we found no studies in the literature that determined how much fatigue affects the postural stability of soccer players during static or dynamic activities. Therefore, the objective of the present study was to evaluate the effect of muscle fatigue induced by high-intensity exercise on the postural stability of soccer players in a dynamic situation simulating the most characteristic motor skill of the sport: the short-pass.

METHODOLOGICAL PROCEDURES

Participants

Thirty male soccer players aged 14 to 16 years participated in the study after its approval by an ethics in research committee. All athletes were members of the same sports club, presented the same weekly training load consisting of five sessions of systematized training, and participated in state and national competitions.

The following inclusion criteria were adopted: 1) playing soccer for at least 3 years and training with the team participating in the study for at least 6 months; 2) absence of musculoskeletal injuries during the period of the tests; 3) absence of any symptoms or special health condition that could interfere with test performance (e.g., cold, flu, fever and/or any discomfort); 4) presentation of the free informed consent form signed by the responsible person prior to the experiment.

Procedures

All procedures were performed in the laboratory at a controlled temperature of 24°C. First, anamnesis was obtained and height, body weight and lower limb length (distance between the greater trochanter of the femur and lateral malleolus) were measured. Next, the participants were submitted to pre-exercise stabilometric assessment, a maximal exercise protocol, and post-exercise stabilometric assessment.

Stabilometric assessment – An AccuSway Plus stabilometric platform (50 x 50 x 4.4 cm) equipped with the Balance Clinic software (Advanced Mechanical Technology, Phoenix, AZ, USA) was used for stabilometric assessment. Two evaluations were performed, one before the protocol used for the induction of muscle fatigue and the other exactly 3 min after the end of the protocol.

First, the supporting foot of the nondominant leg of the athlete was placed on an A4 paper, which was attached to the center of the platform and marked with an X-axis and Y-axis. The center of the plantar arch was aligned with the X-axis and the second toe was aligned with the Y-axis. According to the requirements of the system, four landmarks were marked by applying pressure on the platform: one point on the big toe, one on the fourth metatarsus and two on the calcaneus (one lateral and the other medial). The contour of the athlete's foot was drawn on the paper to guarantee that the exactly same position was maintained in the post-exercise evaluation.

An official soccer ball was aligned with the intersection point between the front edge and lateral border of the platform at a distance corresponding to 30% of the length of the dominant leg (i.e., the passing leg) of each athlete. The volunteer was asked to maintain a one-legged stance position with the supporting foot (nondominant leg) on the platform and the dominant leg suspended (knee flexion sufficient so that the athlete's foot would not touch the ground) for approximately one second before performing the pass with the medial region of the foot (Figure 1), the so-called short-pass. Only passes hitting the target, i.e., a mini-goal (80 cm wide and 45 cm high) located 2.5 m from the front edge of the platform, were considered to be valid. In view of the training level of the athletes, the motor task requested is considered to be of low complexity. Nevertheless, the athletes were allowed to perform three movements for familiarization prior to the test. Standard instructions were provided so that the athletes hit the target and used the same force as applied in the field. In the pre-exercise assessment, the volunteer performed as many attempts as necessary to hit the target (a maximum of two attempts were necessary) and the first valid attempt was considered for analysis. In the post-exercise condition, only one attempt to hit the target was allowed and cases in which the task was not completed adequately were excluded from the analysis.

The data were collected at a sampling frequency of 100 Hz. Three seconds corresponding to the time necessary for execution of the short-pass movement and reestablishment of the initial position were selected for subsequent analysis, which was performed without any signal filtering process. In view of the objectives of the study, the following parameters obtained in the stabilometric assessment were analyzed: 1) total amplitude of the COP displacement along the X-axis (medial-lateral displacement, in cm); 2) total amplitude of the COP displacement along the Y-axis (anterior-posterior displacement, in cm), and 3) mean velocity of the COP displacement over the three seconds of movement evaluation (in cm/s)[20].

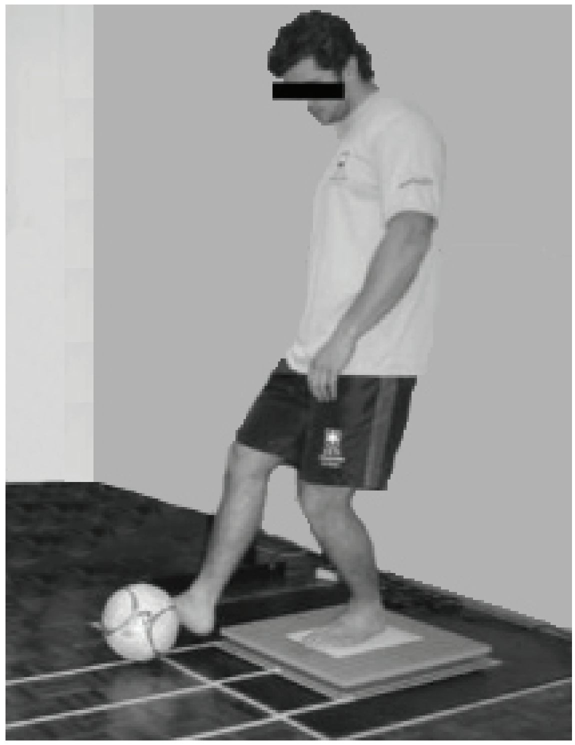

Figure 1. Athlete performing the stabilometric assessment.

Fatigue protocol – A Biotec 2100 AC cycle ergometer equipped with the Ergometric 6.0 software (CEFISE, Nova Odessa, SP, Brazil) was used for the induction of fatigue as proposed by Martin et al.[21]. This protocol was chosen since it has been shown to be efficient in the generation of fatigue in professional athletes. The protocol comprises three Wingate tests (30 s of exercise on a cycle ergometer at maximum velocity against a resistance corresponding to 7.5% of the body weight of each athletes), with 2-min intervals between each test. The fatigue index (calculated based on the data referring to the work performed in the first and third series of the exercise protocol) was obtained directly from the software and used for the measurement of the degree of exercise-induced fatigue.

Statistical analysis

Performance of the players in the pre- and post-exercise stabilometric assessments was compared by the Student t-test for paired samples, adopting a level of significance of $p<0.05$. The results are reported as the mean ± standard deviation in the text and figures.

RESULTS

Three athletes did not validate the stabilometric assessment after exercise since they missed the target. Thus, statistical analysis included the results of 27 subjects. These participants had a mean age of 15.07 ± 0.78 years, mean height of 172.41 ± 6.8 cm, and mean body weight of 63.79 ± 7.65 kg. With respect to performance in the cycle ergometer exercise protocol, a high fatigue index (60.93 ± 6.84%) demonstrated the efficiency of the protocol used for the induction of muscle fatigue in the volunteers.

Despite a mean variation of 15.23%, no significant differences were observed in the amplitude of displacement in the medial-lateral direction between the pre-exercise (1.51 ± 0.27 cm) and post-exercise (1.74 ± 0.89 cm) assessments. However, the mean amplitude of displacement in the anterior-posterior direction increased significantly (21.77%, p=0.004) from the pre-exercise (3.72 ± 0.85 cm) to the post-exercise (4.53 ± 1.32 cm) assessment (Figure 2). In addition, the athletes presented a significant increase (p=0.022) of 31.36% in the mean velocity of COP displacement from the pre-exercise (4.91 ± 0.91 cm/s) to the post-exercise stabilometric assessment (6.45 ± 2.99 cm/s) (Figure 3).

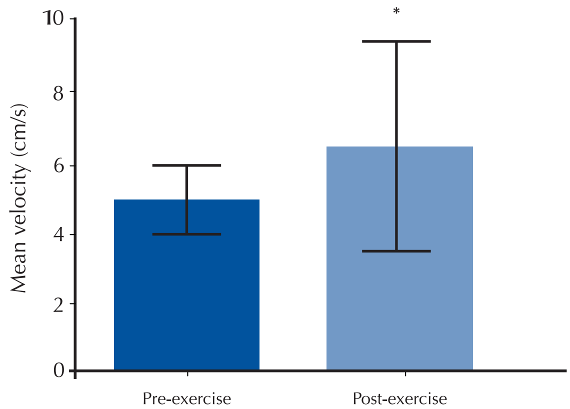

Figure 3. Mean velocity of the center of pressure displacement. * significant difference between pre-exercise and post-exercise (p<0.05).

DISCUSSION

The main finding of the present study is that fatigue significantly compromises the postural stability of soccer players. Since the mean velocity and amplitude of COP displacement are reliable indicators of the postural stability of an individual[5], the results demonstrate that fatigue negatively affects the ability of athletes to maintain their balance during the pass movement. Although no significant difference was observed in the medial-lateral displacement values, the variation of approximately 15% between the pre- and post-exercise evaluations suggests a tendency towards an increased instability also in the medial-lateral direction, in agreement with the findings obtained for the other variables analyzed.

Studies have reported changes in posture control related to fatigue induced by exercises that consisted of isokinetic dynamometry of isolated regions such as the ankle[8], hip[22] and lumbar spine[23], as well as by multi-joint exercises[4]. However, studies using global and cyclic exercises (e.g., cycling and running)[10,11] better illustrate the situations experienced during exercise in which fatigue is established in the individual. The reduction in stability due to muscle fatigue has also been investigated using bilateral stance testing[4,14]. However, the importance of single stance testing is based on the fact that this type of analysis resembles situations in which most lower limb injuries occur[8]. In addition, the choice of a dynamic stabilometric test involving a characteristic skill of the sport permits to draw more concrete inferences between the results ob-

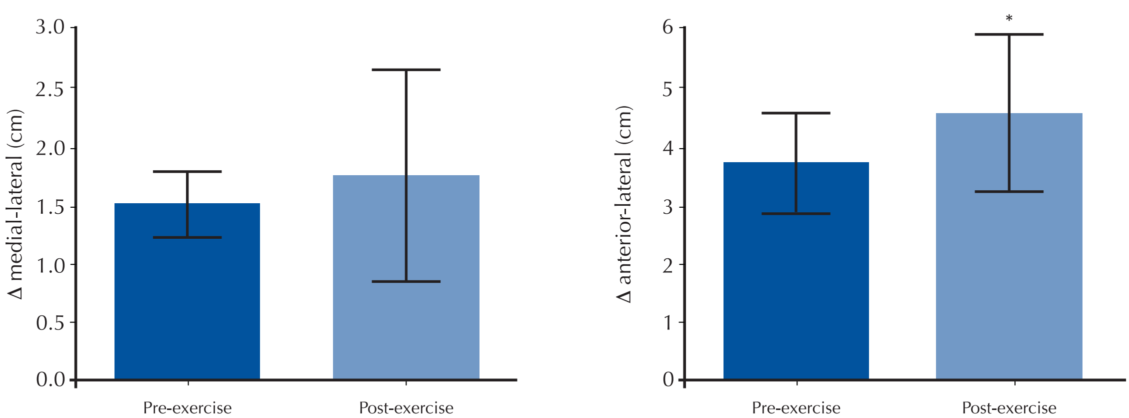

Figura 2. Amplitude of the center of pressure displacement (Δ) in the medial-lateral and anterior-posterior direction.
* significant difference between pre-exercise and post-exercise (p<0.05).

tained and the performance of the athletes during the sport. In this respect, although we found no quantitative studies reporting the effect of lower limb fatigue on the short-pass in soccer that could be compared with the present investigation, some studies quantitatively analyzed similar movements, such as kicking[18], or subjectively analyzed the short-pass[24] after muscle fatigue development.

Apriantono et al.[18] investigated the kinetics and kinematics of instep kicking, known as "shooting", and observed a performance decline after a fatigue exercise protocol. The authors concluded that fatigue not only reduced the muscle's force-generating capacity, but also affected the effective action of the segment in terms of movement coordination. Similarly, Rampinini et al.[24], using a short-passing skill test (Loughborough Soccer Passing Test), demonstrated a decline in the short-passing proficiency of professional soccer players during a match. Although evidence indicates that balance training may increase the posture control of athletes[9], the present results and those reported in the studies cited above[18,24] highlight the need of good physical conditioning in order to preserve the posture control and the adequate execution of the motor task during a soccer game. This inference is supported by the findings of Impellizzeri et al.[25], who observed an increase of performance in a short-passing skill test after a period of aerobic training.

Although the present study does not permit to determine the origin of the reduction in posture control due to fatigue, evidence in the literature indicates a deleterious effect of fatigue on articular proprioceptive ability as a possible mechanism[26]. This proprioceptive impairment is due to an increase of the muscle spindle discharge threshold, interrupting afferent feedback and consequently altering articular sensitivity[27]. This reduced somatosensory input leads to alterations in reflex and voluntary muscle responses that result in deficient neuromuscular control and a consequent decrease of static and dynamic posture control.

Two strategies are commonly used for balance maintenance: the hip strategy and the ankle strategy[28]. Since the cycle ergometer exercise used in the present study overloads the proximal and distal muscles of the lower limb in a distinct manner[29], a higher level of fatigue is expected for the thigh muscles compared to leg muscles. This could be a key factor to explain the greater instability in the anterior-posterior direction, which compromises the hip strategy due to proximal muscle fatigue[30] and reduces imbalance in the medial-lateral direction. Further studies are needed to determine the effect of exercise on posture control in soccer players using their running skills, a situation in which the medial-lateral instability is probably greater than in the present study.

The main limitation of the present study is exactly the fact that a cycle ergometer was used for the induction of fatigue. Although the most adequate procedure for the induction of fatigue would be an exercise protocol similar to the situation experienced by soccer players in the field, it was not possible to use the stabilometric platform outside the research laboratory. In addition, no physical space was available in the laboratory at the time of data collection for specific tests involving running skills and we did not have an adequate ergometric treadmill for maximum exercise protocols in athletes, therefore a cycle ergometer protocol was used. Furthermore, the platform was not aligned with ground level, a fact that distinguishes the skill tested in the laboratory from field skills and limits extrapolation of the results to soccer practice. However, it does not alter the findings regarding the effect of fatigue since the same skill was used during the pre- and post-exercise evaluations.

CONCLUSION

Muscle fatigue induced by high-intensity exercise significantly affects the postural stability of adolescent soccer players. Dynamic stabilometric assessment used in the present study permits to infer that this change in the ability of stability maintenance reduces short-pass performance in the field. From a practical point of view, this study supports the premise that the precision in specific motor skills of the modality, such as the short-pass, should be improved not only by technical training of the movement, but also by adequate physical conditioning to reduce as much as possible the development of muscle fatigue during a soccer game, thus improving the execution of the specific motor skills of the sport.

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Address for Correspondence
Bruno Manfredini Baroni
Universidade Federal do Rio Grande do Sul (UFRGS)
Escola de Educação Física (ESEF);
Laboratório de Pesquisa do Exercício (LAPEX)
Rua Felizardo, 750 – Bairro Jardim Botânico.
CEP: 90690-200 - Porto Alegre, RS. Brasil.
E-mail: bmbaroni@yahoo.com.br