The analysis of COP and joint position sense in university soccer players with and without ankle instability

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Abstract

The aim of the study was to compare the behavior of COP and passive ankle position sense in subjects with and without functional ankle instability. Took part in this study 20 subjects, divided into two groups: stable group (SG) and unstable group (UG). The COP evaluation was made with the single-leg balance test, with eyes opened and closed, on a force plate. The passive ankle position sense test was performed with subjects blindfolded. The ankle was positioned in a target angle (10° and 20°) and the dynamometer moved passively the ankle, then the subjects were instructed to push the stop button when they feel that the ankle was on the target angle, obtaining the absolute angular error (AAE). The following variables were obtained: total displacement (TD); antero-posterior (SDap) and medio-lateral standard deviation (SDml); total mean velocity (TMV); antero-posterior (MVap) and medio-lateral mean velocity (MVml). The comparison between the data with normal distribution was made with the Student's t test, while to the TD and SDml was used the Mann-Whitney test. The correlations were performed with the Pearson and Spearman tests. We adopted $\alpha < 0.05$. We observed difference between AAE-10º ($p < 0.05$). Strong correlations were found between: AAE-10° and TMV ($p < 0.01$ $r = -0.867$); AAE-10° and MVap ($p < 0.01$ $r = -0.854$); AAE-10° and MVml ($p < 0.01$ $r = -0.771$), with eyes opened, and AAE-10° and TD ($p < 0.05$ $r = -0.666$); AAE-10º and SDap ($p < 0.05$ r = -0,685) and AAE-10° and MVml ($p < 0.05$ $r= -0.766$) with eyes closed. Ankle sprains harm the joint position sense without affecting the balance.

Key Words: Ankle sprain; Proprioception; Balance; Biomechanics.

Introduction

The soccer is one of the most popular sport modality around the world, with millions of practitioners of different levels, and thus, the incidence of injuries are expressive[1-3]. Among these injuries, the ankle sprain is the one that stands out[2, 4-5].

The ankle sprains are very common in soccer due to the demand of changes in direction performed with high velocities, after jumps and during the sprints itself[2, 4, 6]. These rapid changes in direction or landing on irregular surfaces produces a large supination torque, causing the ankle to perform an excessive movement, overloading the joint and its structures, mainly the anterior talo-fibular and the calcaneo-fibular ligaments[7].

Repeated episodes of ankle sprains may negatively affect the proprioception, which correspond to the perception of position and movement (i.e., synesthesia) of the body and its segments[8-9]. These information are provided by mechanoreceptors in the muscles, tendons, skin, joint capsules and ligaments[10-12]. These mechanoreceptors are sensitized by mechanics energy imposed to the joint and it is transmitted to the central nervous system by afferents impulses[13]. As a consequence to sprains, the afferent fibers of the mechanoreceptors joints become damaged, impairing particularly the joint position sense, resulting in a situation known as the functional ankle instability (FAI)[14-16], which is defined by Freeman[17] as a complain of "false subjective perception". Hertel[18] attributed its causes to deficits in the joint position sense, reduced muscle strength, delay in fibular muscles activation, equilibrium deficits, alterations in the activity of the fibular nervous and decrease in the dorsiflexion range of the movement, and its residuals symptoms may remain for long periods[19].

Due to its proximity with the base of support, the ankle is essential to the balance maintenance, and the proprioceptive deficit evoked by the FAI tends to worst the postural stability control, as a consequence to the larger displacement of the center of pressure (COP) and also resulting in a longer time to recovery the stability[8, 20-23]. Garn and Newton[24] observed that individuals with FAI present losses in the joint position sense, which could be one of the reasons for the lower performance in the COP stabilization.

The aims of the present study were to compare the behavior of the COP displacement and the passive ankle position sense between practitioners of field- and indoor-soccer with and without FAI, as well as to verify the relationship/correlation between the passive ankle position sense and the displacement of the COP variables.

Method

Sample

Twenty male individuals that take part in field- and indoor-soccer at the university level, with a minimum of three years of experience, were allocated in one of two groups: without functional ankle instability (stable group - SG) or with functional ankle instability (unstable group - UG). For the SG the ankle were classified as dominant (D) and non-dominant (ND); for the UG the ankle were classified as stable (E) or instable (I), despite dominance. For between groups comparison purpose the dominant ankle of the SG were paired with the unstable ankle of the UG, given that previous studies did not demonstrate significant difference on COP behavior between the dominant and non-dominant lower limbs of healthy individuals[25-26]. Both groups had a training frequency of three times a week, and participated in three championship during the whole year. The individuals' characteristics are presented in TABLE 1. The perceptual of body fat were measured with the skinfolds method[27] and the body density was calculated accordingly[28].

TABLE 1 - Groups' characteristics.

	SG (n = 10)	UG (n = 10)
Age (years)	23.89 ± 2.85	21.70 ± 2.71
Height (m)	1.75 ± 0.05	1.74 ± 0.04
Body mass (kg)	79.40 ± 8.35	71.88 ± 6.94
BMI (kg/m^2)	25.93 ± 1.61	23.72 ± 1.83
Body fat (%)	21.12 ± 2.28	20.05 ± 2.49
Time experience (years)	13.00 ± 5.12	10.80 ± 5.45

SG: stable group;
UG: unstable group;
BMI: body mass index.

The groups were divided according to the Cumberland Ankle Instability Tool (CAIT) score, proposed by Hiller et al.[29], which was adapted to the Brazilian population by Noronha et al.[30]. The questionnaire is composed by nine multiple-choice questions, with scores between zero to 30, whereas the higher the score the better the ankle condition. The threshold that separate individuals with higher risk to develop FAI was 27, and scores ≤ 24 indicates moderate FAI[29, 31-32]. For the present study, a score of 24 was adopted as a cut point, whereas individuals with values lower or equal to 24 were classified as unstable. The scores for both groups are presented in TABLE 2.

The present study did not include individuals with sprains of degree I or II in the last six months, ankle sprains of degree III, fractures in the lower limbs, surgical procedures to the lower limbs, vestibular disorders, and/or mechanic instability evaluated by the test of anterior laxity and talus inclination.

TABLE 2 - Cumberland Ankle Instability tool (CAIT) score for both groups.

Groups	D/U	ND/S
SG (n = 10)	27.50 ± 1.84	27.10 ± 1.60
UG (n = 10)	20.30 ± 4.03	26.00 ± 2.87

SG: stable group; UG: unstable group; D/U: dominant ankle/unstable, ND: non-dominant ankle/stable.

Evaluations

Initially, the anamnesis, ankle sprain historic, physical characteristics and anthropometric data were collected. Additionally, it was performed the dominance test for lower limbs, as well as the test of the ankle inversion and eversion goniometry. Then, subjects performed a single-leg support test on the force platform and the passive ankle-repositioning test in the isokinetic dynamometer.

The dominance tests were composed of kicking a ball in a target of one meter of width positioned at 10 meters away; climb a step with 20 cm of height; and recovery the balance after a hard push applied in the middle point between the shoulder blades in an anterior-posterior way, causing the subject to give a step forward to maintain balance.

TABLE 3 depicted the goniometry values.

TABLE 3 - Goniometry (degrees) of inversion and eversion for both groups.

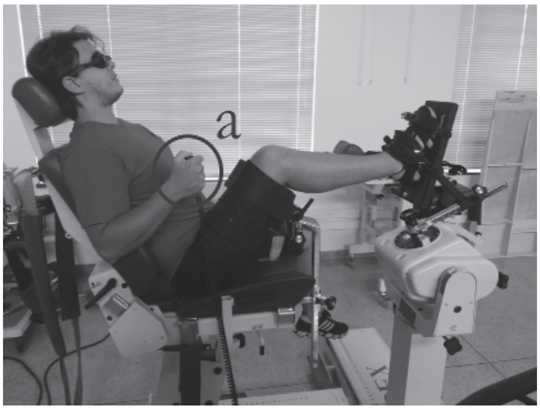
	INV		EVE	
	D/U (º)	ND/S (º)	D/U (º)	ND/S (º)
SG (n = 10)	28.80 ± 4.34	30.20 ± 4.16	18.20 ± 3.19	19.00 ± 4.24
UG (n = 10)	27.80 ± 5.03	28.40 ± 3.24	16.60 ± 4.53	18.80 ± 5.98

SG: stable group; UG: unstable group; INV: inversion; EVE: eversion; D/U: dominant/unstable ankle; ND/S: non-dominant/stable ankle.

After anamnesis, the subject was familiarized with the single-leg balance test. The subject was positioned in the center of the force platform (OR6-6; AMTI®), with an acquisition frequency of 2000 Hz, and it was instructed to hold on the single-leg position for 20 seconds. Data were collected throughout the ForceNet (AMTI®) software. The lower limb that maintained contact with the force platform was held with a small knee flexion and a neutral position for the ankle, whereas the lower limb suspended hold on with the hips and knee flexed (FIGURE 1). The single-leg balance test was performed with the eyes open and with eyes closed (blindfolded), with both the lower limbs. During the test with the eyes open a circular target were positioned in front of the subjects[34-35]. Three attempts was performed for each condition with a 20 seconds rest interval between them. If the subject performed any kind of jump, or touched the floor/platform with the suspended limb the test was repeated[36-38]. Three attempts were allowed in order to familiarize the subjects to the balance test protocol.

FIGURE 1 - Equilibrium test with single-leg support.

After that, the passive ankle position sense test was performed. The test was performed in a dynamometer isokinetic Byodex System 4 Pro (Biodex®), with a sample frequency of 100 Hz. The data were collected using the Biodex Advantage software (Biodex®). Firstly, the researcher positioned the ankle of the subject passively, starting from a neutral position, with angular velocity of 1º/s, with 10º of inversion and held for 10 seconds. After that, the dynamometer was adjusted to perform the movement with an angular velocity of 1º/s. Then, the subject was instructed to reposition the segment at the same angle in which it was held for 10 seconds, stopping the dynamometer manually by pressing the stop button. The same procedure was repeated for the 20º of inversion position[39-42]. The difference between the position establish by the protocol and the one assumed by the subject was considered as the proprioceptive deficit (absolute angular error - AAE, in degrees). The test was performed twice with the subject blindfolded to avoid any visual support (FIGURE 2). The subjects had up to two attempts to familiarize with the procedure. This procedure was performed for both lower limbs.



a: device to stop the movement of the dynamometer.

FIGURE 2 - Passive reposition joint test.

Data processing

For the analysis of the single-leg balance test, the signal of the force platform was processed with the 4º order Butterworth low-pass with a cut-off filter of 95 Hz, defined by the residual analysis[43]. The following variables related to the displacement of the center of pressure were observed:

- Total displacement (TD): sum of the root mean square of the squares of the displacement in the anterior-posterior displacement and medium-lateral during the 20 seconds of test;

- Standard deviation anterior-posterior (SDap): standard deviation of the mean of the displacement in the anterior-posterior direction during the 20 seconds of test;

- Standard deviation medium-lateral (SDml): standard deviation of the mean of the displacement in the medium-lateral during the 20 seconds of test;

- Total mean velocity (TMV): mean of the velocity of the displacement in the anterior-posterior and medium-lateral direction during the 20 seconds of test;

- Anterior-posterior mean velocity (MVap): mean of the velocity of the displacement in the anterior-posterior direction during the 20 seconds of test;

- Medium-lateral mean velocity (MVml): mean of the velocity of the displacement in the medium-lateral direction during the 20 seconds of test;

The data regarding the passive joint reposition were obtained with the Biodex Advantage (Biodex®) software. The AAE values were acquired for the angle of 10º (AAE-10º) and 20º (AAE-20º).

Statistical analysis

Data were analyzed with the SPSS Statistic 18.0 (SPSS®) software. Firstly, all data were tested for normality, after that, the statistical test was used accordingly.

All data considered normal according to the Shapiro-Wilk test were analyzed with the Student t test. Only the variables TD and SDml did not met the criteria for normality, thus, they were analyzed with the Mann-Whitney test. Similarly, the relationship between variables for the normal data was performed with Pearson' correlation; for the non-normal data the Spearman's correlation was used. The significant level for all variables was set as $\alpha < 0.05$.

Results

TABLE 4 depicted the center of pressure displacement, TD, SDap, SDml, TMV, MVap, MVml, during the single-leg balance test with the eyes open (EO) and eyes closed (EC) in the SG and UG.

TABLE 4 - Variables of the center of pressure during the single-leg balance test with the eyes open and eyes closed.

Variables	Eyes open		Eyes closed	
	SG (n = 10)	**UG (n =10)**	**SG (n = 10)**	**UG (n =10)**
TD (mm)	310.22 ± 39.52	302.55 ±6.07	568.27 ± 151.15	712.13 ± 243.20
SDap (mm)	0.0070 ± 0.0012	0.0069 ± 0.0015	0.0153 ± 0.0043	0.0189 ± 0.0074
SDml (mm)	0.0049 ± 0.0011	0.0051 ± 0.0015	0.0077 ± 0.0021	0.0093 ± 0.0032
TMV (m/s)	0.0792 ± 0.232	0.0743 ± 0.0156	0.1679 ± 0.0659	0.2171 ± 0.0875
MVap (m/s)	0.0680 ± 0.0201	0.0651 ± 0.0004	0.1469 ± 0.0580	0.1849 ± 0.0837
MVml (m/s)	0.0284 ± 0.0095	0.0246 ± 0.0035	0.1679 ± 0.0659	0.2171 ± 0.0875

SG: stable group; UG: unstable group; TD: total displacement; SDap: anterior-posterior standard deviation; SDml: medium-lateral standard deviation; TMV: mean total velocity; MVap: anterior-posterior mean velocity; MVml: medium-lateral mean velocity.

TABLE 5 depicted the absolute angular errors at angles 10º (AAE-10º) and 20º (AAE-20º) during the passive joint reposition test, performed by the SG and UG, in which it was observed statistical differences between the AAE-10º in the dominant/unstable ankle.

The results regarding the correlations between AAE and COP variables are depicted in TABLE 6. It were observed strong correlations only in the UG between: AAE-10º and TMV (p = 0.001 and r = -0.867); AAE-10º and MVap (p = 0.002 and r= -0.854); AAE-10º and MVml (p = 0.009 and r = -0.771), in the eyes open condition, and AAE-10º and TD (p = 0.036 and r = -0.666); AAE-10º and SDap (p = 0.029 and r = -0.685) and AAE-10º and MVml (p = 0.01 and r = -0.766) in the eyes closed condition.

TABLE 5 - Between-groups comparison for absolute angular error (AAE) in the passive joint reposition test.

Angle	SG (n = 10)	UG (n = 10)
AAE-10º (º)	1.29 ± 0.90	2.82 ± 1.70*
AAE-20º (º)	1.89 ± 1.33	1.73 ± 1.17

SG: stable group, UG: unstable group. * Significant different to SG (p<0.05.

TABLE 6 - Correlation coefficient between the absolute angular error and the center of pressure variables.

AAE x	10°								20°							
	EO				EC				EO				EC			
	SG	r	UG	r	SG	r	UG	r	SG	r	UG	r	SG	r	UG	r
TD	0.700	-0.595	0.632	-0.321	0.872	0.590	0.036*	-0.666	0.680	0.149	0.235	-0.413	0.656	0.162	0.463	-0.263
SDap	0.099	-0.551	0.248	-0.517	0.996	-0.002	0.029*	-0.685	0.234	0.414	0.258	-0.395	0.947	-0.024	0.447	-0.272
SDml	0.583	-0.198	0.126	-0.201	0.875	0.057	0.103	-0.546	0.290	-0.372	0.427	-0.284	0.639	-0.17	0.574	-0.203
TMV	0.362	-0.362	0.001**	-0.867	0.995	0.002	0.082	-0.575	0.137	0.137	0.949	0.023	0.598	0.19	0.403	-0.298
MVap	0.399	-0.301	0.002**	-0.854	0.963	0.017	0.179	-0.462	0.160	0.160	0.990	-0.004	0.672	0.153	0.743	-0.119
MVml	0.32	-0.351	0.009**	-0.771	0.825	-0.081	0.01*	-0.776	0.135	0.135	0.618	0.180	0.385	0.309	0.587	-0.196

AAE: absolute angular error; EO: eyes open; EC: eyes closed; SG: stable group; UG: unstable group; TD: total displacement; SDap: anterior-posterior standard deviation; SDml: medium-lateral standard deviation; TMV: total mean velocity; MVap: anterior-posterior mean velocity; MVml: medium-lateral mean velocity.

Discussion

The present study compared the displacement of the center of pressure and the joint position sense of university students that practiced soccer with and without FAI.

The variables related to COP did not present significant differences between the SG and UG in the present study. Ross et al.[37] observed that individuals with FAI exhibited higher values for TD, SDml, MVap and MVml. However, these authors demonstrated that the most sensible variables to distinguish between individuals with and without FAI were the standard-deviation of the median-lateral ground reaction force (GRF-SDml) and the anterior-posterior stabilization time (STap), though, neither were analyzed in the present study. Hertel and Olmsted-Kramer[35] showed that traditional measures of the COP, may not be sensible enough to detect differences between individuals with and without FAI, given that MVap was the only variable (among other eight) that exhibit significant differences between these individuals. In the present study, we believed that the lack of difference between groups might be related to the characteristic of the single-leg test used. Ankle sprains are associated to fast movements, such as jumps, sprints and changes in direction[2, 4-6, 8]; however, the measures used herein, stabilization time and COP reposition in the support, are more accurate to differentiate between individuals with and without stability[35, 37].

Additionally, another factor that may have influenced our results is the period of the sprain event[35, 37]. Holme et al.[44], McKeon and Hertel[45] and Hertel et al. [46] claimed that the negative effects associated with this type of injury on the postural control may be more apparent in acute phases. Holme et al.[44], showed that the postural control returned to normal condition after four months of the injury incident (i.e., ankle sprain), even though no treatment has been carried out. However, a 12 months follow-up demonstrated that only 7% of the athletes that performed the rehabilitation presented another sprain, while 29% that did not perform any treatment exhibited another injury incident. McKeon and Hertel[45] also observed a lower incidence risk for injury after six weeks of rehabilitation treatment. Hertel et al. [46] demonstrated that two weeks after the ankle sprain incident there is an acute degradation in the postural control, which returned to normal condition after four weeks of rehabilitation. Although, the results of these studies are not able to explain the FAI occurrence in chronic cases, as for example, in the Konradsen et al.[19] study, whereas the residual symptoms remained for as long as seven year after the injury incident.

In order to diagnose the instability[47] and to prevent ankle sprains, evaluate the position sense and the joint movement, both passively or actively, seems to be crucial[48-49]. Despite of differences between studies' protocols, our results demonstrated a greater error in the joint reposition sense in individuals with ankle instability. In the present study, these errors were more apparent in the joint reposition sense test performed passively at 10º (AAE-10º) between the SG and UG, with no difference at 20º.

The association of the AAE at 10º and 20º with the COP variables showed strong correlations for the UG between AAE-10º and TD, AAE-10º and SDap, AAE-10º and MVml with the eyes closed. The injury caused in the mechanoreceptors impairs the responses and the mechanisms of adaptations related to perturbation in the postural balance and, as expected, these results indicates that the proprioceptive deficit are related to the control of the posture stability[50-51].

In spite of the reduced sample size, the results from the present study demonstrated important indicatives that the FAI impairs the joint position sense in the initial inversion angles. The greater stratification of the angles as well as the balance tests with similar movements to that performed by soccer practitioners may contribute to better understand how the FAI increases the susceptibility to new sprains and the prevalence of residuals symptoms.

The ankle sprain, even if it is old, may influence the position joint sense of soccer player's university students with and without ankle instability, even without impairment in balance. These results point out for a greater attention to training and rehabilitation of this joint and the continuity of a measure with the aim to prevent a new sprain.

Resumo

Análise do COP e sentido de posição em jogadores universitários de futebol com e sem instabilidade de tornozelo

O objetivo do estudo foi comparar o comportamento do COP e do sentido de posição articular passivo em indivíduos com e sem instabilidade de tornozelo, e correlacionar as variáveis de COP e sentido de posição articular passivo. Participaram 20 indivíduos, divididos em dois grupos: grupo estável (GE) e grupo instável (GI). A avaliação do COP foi feita com o teste de apoio unipodal, com olhos abertos e fechados sobre uma plataforma de força. O teste de reposicionamento articular passivo foi realizado com os olhos vendados. O tornozelo foi posicionado em um ângulo alvo (10° e 20°) e o dinamômetro movia passivamente o tornozelo, então os participantes eram instruídos a apertar o botão para parar o movimento quando sentissem que o tornozelo estava no ângulo alvo, obtendo assim o erro angular absoluto (EAA). Foram obtidas as variáveis: deslocamento total (DT); desvio padrão ântero-posterior (DPap) e médio-lateral (DPml); velocidade média total (VMT); velocidade média ântero-posterior (VMap) e médio-lateral (VMml). A comparação entre dados que apresentaram distribuição normal foi feita com o teste t de Student, enquanto que para DT e DPml foi utilizado o teste de Mann-Whitney. Da mesma forma, foram usados os testes de Pearson e Spearman para correlacionar as variáveis. Foi adotado $\alpha < 0,05$. Houve diferença entre EAA-10º ($p < 0,05$). Foram encontradas fortes correlações entre: EAA-10° e VMT ($p < 0,01$ $r = -0,867$); EAA-10° e VMap ($p < 0,01$ $r = -0,854$); EAA-10° e VMml ($p < 0,01$ $r = -0,771$), na condição olhos abertos, e EAA-10° e DT ($p < 0,05$ $r = -0,666$); EAA-10º e DPap ($p < 0,05$ $r = -0,685$) e EAA-10° e VMml ($p < 0,05$ $r = -0,766$) na condição olhos fechados. Entorses de tornozelo prejudicam o sentido de posição, sem afetar o equilíbrio.

Palavras-chave: Entorse de tornozelo; Propriocepção; Equilíbrio; Biomecânica.

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