ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

RUNNING KINEMATIC ANALYSIS IN SUBJECTS WITH AND WITHOUT ANTERIOR KNEE PAIN

[1] Felipe Costa Alvim, [2]Adriane Mara de Souza Muniz, [1]Luciano Luporini Menegaldo and [1]Jurandir Nadal
[1]Programa de Engenharia Biomédica/COPPE-UFRJ, Rio de Janeiro, Brasil
[2]Escola de Educação Física do Exército (EsEFEx), Rio de Janeiro, Brasil
felipe.alvim@gmail.com

SUMMARY
The recent increase in the number of runners has been followed by a increase in absolute number of injuries related to this sport in which anterior knee pain (AKP) is one of the most common. Changes in lower-limb joint angular kinematics have been reported in running practicing subjects. Management of AKP is likely to be improved with a better comprehension of such kinematic patterns. Thirty five recreational runners (15 with anterior knee pain and 20 healthy controls) had their lower limb kinematics recorded during a treadmill running at 11 km/h. Principal component analysis (PCA) was used for reducing data of the average 3D motion of the hip, knee and ankle joints, during running. AKP and healthy subjects PCAs were compared. No differences have been found for ankle joint movement. However, in sagittal and transverse planes of the knee and hip joints differences between the groups were observed. In the sagittal plane, hip extension angle reduction was observed for AKP group. In the transverse plane, the observed hip and knee internal rotation increase can be related to hip external rotators weakness, which is one of the AKP mechanisms described in the literature.

INTRODUCTION
Running is a popular activity, because of its convenience, healthy benefits and low costs. However, the potential for running injuries has been well documented in the literature; especially in the knee joint [1]. Anterior knee pain (AKP) is a commonly cited lower extremity overuse injury, estimated to account for over 20% of all visits to an outpatient sports medicine center. AKP is complex and dependent on quadriceps function, as well as on static and dynamic restraints [2]. Lower limb kinematical pattern modifications during running include: pelvic drop contralateral to stance side, increase in hip adduction and internal rotation and foot hiperpronation, which are associated with etiological factors of AKP. Earl and Vetter (2007) [2] suggested that excessive internal femur rotation beneath the patella might contribute to AKP in some subjects.

A better understanding of running kinematic changes in AKP subjects is likely to improve clinical decisions. The purpose of this study is to assess lower limb kinematic patterns during running in subjects affected by AKP and compare to healthy controls.

METHODS
Thirty five male recreational runners have been enrolled in this study. They were split in two groups, one containing 15 individuals reporting anterior knee pain (AKPG) related to running (averaged age 27.7 ± 2.9 years, height 1.8 ± 0.1 m and weight 74.2 ± 9.1 kg) and the other with 20 pain-free runners (CG) (age 29.1 ± 4.4 years, height 1.7 ± 0.1 m and weight 74.9 ± 8.2 kg). All subjects were required to be running a minimum of 15 km per week at least two years prior to this study. The exclusion criteria were traumatic knee joint, patellar injury and ligament or meniscus disorder. All subjects signed a written informed consent approved by a local ethics committee.

Subject kinematics data were assessed during treadmill running at 11 km/h for 15 s after 10 min adaptation. All participants wore the same neutral running tennis shoes. Lower limb 3D kinematics was reconstructed using four digital cameras (Qualisys System, Sweden), sampled at 200 Hz. Nine reflexive markers were placed following Helen Hayes marker set. Additional fifth metatarsal head marker was placed to improve the frontal foot movement calculation. Euler angles for the ankle, knee and hip were calculated using Visual 3D software (C-Motion, Rockville, MD). Segment and joint kinematics were normalized to the static trial.

The running cycle was determined using foot velocity algorithm [3]. Angular displacements curves were filtered using 2nd order bidirectional Butterworth low-pass filter with cutoff frequency of 8 Hz. The signals were interpolated and resampled with 101 points according to the running cycle and used afterwards to obtain the averaged waveform of each joint in all movement planes. Signals from each analyzed joint were stored in a matrix **E** (35 x 303). The rows correspond to one subject (# 20 CG and # 15 AKPG), while each column contains the kinematic data from sagittal, frontal and transverse planes, respectively. Principal component analysis (PCA) was applied to the covariance matrices **S** (303 x 303) from ankle, knee and hip joints, according to Jolliffe (2004) [2]. For each joint, the relevant Principal Components (PCs) were selected by the scree test [4].

Wilcoxon rank sum test was applied to verify statistical differences in PC scores retained in the analysis for each joint between controls and AKPG subjects. The eigenvectors corresponding to the PC scores with statistical differences were analyzed to interpret the group differences. The significance level was $\alpha = 0.05$. All signal processing procedures were implemented in Matlab 6.5 (The Mathworks, USA).

RESULTS AND DISCUSSION

According to scree test 5 PCs from ankle, 4 for knee and 5 for hip were retained in the analysis, representing respectively 85.5 %, 86.6% and 91.8% of total variance of each signal. However, only the first PC score for knee ($p = 0.0263$) and for hip ($p = 0.0260$) joints presented statistical difference between controls and AKP subjects. Therefore, these results suggest that the most important kinematic differences between runners with and without AKP occur in the knee and hip joints. This finding is not in accordance with other authors, such as Earl and Vetter (2007) [2], who reports ankle joint movement changes in AKP runners.

The loading factor analysis of the PCs that presents statistical differences between groups may shed light on the interpretation of PC analysis. Each PC sample constitutes the loading factor attributed to the corresponding sample of the original signal, with higher absolute loading factors pointing to the epochs of higher variance between groups within the original waveforms [5]. The comparison between the first PC and the original knee kinematic waveforms suggests that the principal differences rely on sagittal and transverse planes (Figure 1). In the knee joint, the highest loading factors were found on the saggital and transverse planes (Figure 2b). On the sagittal plane, AKPG presented higher knee flexion angle (Figure 1a) during the stance phase. This change may be attributed to some pain avoiding compensation mechanism, either changing the rigid-body dynamic behavior or related to muscle function. On the transverse plane, AKPG presented higher knee internal rotation compared to pain-free subjects. This pattern could be possibly assigned to an insufficient strength of hip external rotators muscles. As a consequence, the position of the lower limb presents internal femur rotation and patellofemoral misalignment [2].

For the hip joint, first PC analysis evidenced differences during all running cycle in sagittal and transverse planes (Figure 2b). On transverse plane an overall increase in the internal rotation (Figure 2a) was found, similarly to the knee. These findings can be related to the hip external rotators weakness, leading to increased internal knee rotation [2].

CONCLUSIONS

The AKP runners demonstrated knee and hip kinematic differences in sagittal and transverse planes compared to controls. Knee flexion increases during stance and hip extension reduces along the whole running cycle that can possibly be associated to some kind of pain compensation mechanism. Furthermore, the increased hip and knee internal rotation during all running cycle can be associated to hip external rotators weakness, causing patellofemoral joint misalignment.

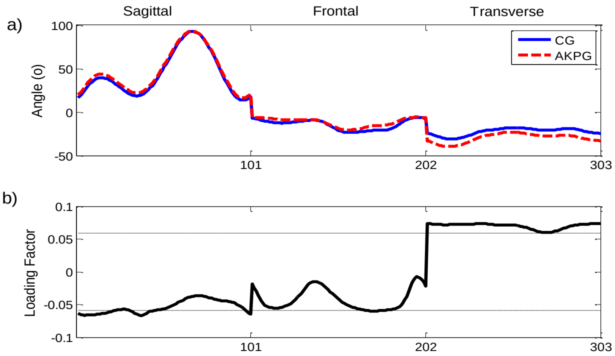

Figure 1 – a) Averaged knee kinematics. b) The corresponding first principal component (The dashed line corresponded to 80 % of the maximum loading factors). In x-axis, points between 0 to 101 correspond to sagittal plane motion, between 102 to 202 to frontal plane and between 203 to 303 to transverse.

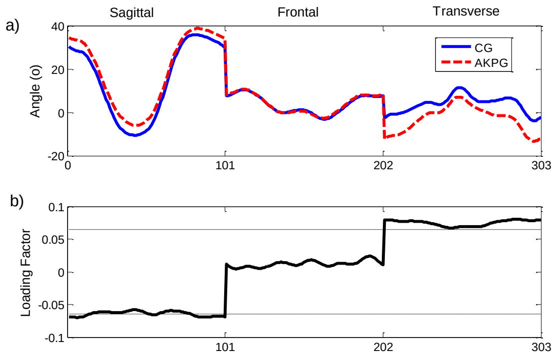

Figure 2 - a) Averaged hip kinematics.. b) The corresponding first principal component (The dashed line corresponded to 80 % of the maximum loading factors). In x-axis, points between 0 to 101 correspond to sagittal plane motion, between 102 to 202 to frontal plane and between 203 to 303 to transverse.

ACKNOWLEDGEMENTS

The authors would like to thank to the Brazilian agencies FAPERJ, CAPES, CNPq and FINEP for the financial support.

REFERENCES

1. Earl, J. E. e Vetter, C.S. Patellofemoral Pain. *Phisical Medicine and Rehabilitation Clinics of North America.* **18**: 439-458, 2007.
2. Jolliffe IT, *Principal component analysis*. 2nd ed. 2002, New York: Springer.
3. O’Connor, et al. Automatic detection of gait events using kinematic data. *Gait and Posture.* **25**:469-474, 2007.
4. Tauton, J. E. et al. A retrospective case-control analysis of 2002 running injuries. *British Journal of Sports Medicine.* **36**:95-101, 2002.
5. Deluzio, K.J. e Astephen, J.L. Biomechanical features of gait waveform data associated with knee osteoarthritis an application of principal component analysis. *Gait and Posture.* **25**(1)-86-93, 2007.