RUNNING PATTERN DIFFERENCES IN GENDER AND RUNNING LEVEL

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As biomechanists, improving technique with an aim of injury prevention is an essential application of biomechanics in recreational runners. A mixed sample of elite and recreational runners, belonging to either sex, could give useful movement patterns of movement. In order to obtain any useful pattern of movement we would like to know if we should use an elite or a recreational sample as a reference also differencing in sex. A total of 48 runners participated in this study: 12 female amateurs, 38 male amateurs and 8 male professionals. Running gait parameters and sagittal plane kinematics from the hip, knee and ankle and frontal plane kinematics from the foot were recorded at a self-selected speed for the amateurs and the speed of the elite athlete was adapted to that of the amateurs. Differences in sex were found at the self-selected speed, stride length and hip extension at foot off ($p<0,005$). Differences in running level were found in the swing phase and in knee flexion at foot contact.

KEY WORDS: kinematics, sagittal plane, gait parameters, comparison, amateur and elite.

INTRODUCTION: The number of recreational runners are increasing globally. In Spain the 2012 National Sport Counsel Review recorded more than 2 million runners. The San Silvestre Run at Madrid City this 2016 December has had more than 40.000 participants. Non-elite runners go to the running biomechanics specialists more often, looking for advice in order to improve their performance and prevent injuries. On the other hand, the biomechanists' need to find a pattern reference for comparing, analysing and improving the running technique of their clients. The first strategy could be to look for this model at the scientific literature. Another possibility chance is to use one's own runner database for obtain a reference model or technical pattern, but this raises up two main questions: i) Should we use a recreational or an elite sample? ii) Is it necessary to differ between the sexes? There are several studies that analyse unhealthy running patterns comparing both injured and non-injured runners (Milner, Hamill, & Davis, 2010; Noehren, Pohl, Sanchez, Cunningham, & Lattermann, 2012). Other studies offer information about elite (Daly, McCarthy Persson, Twycross-Lewis, Woledge, & Morrissey, 2015) or recreational runners (Noehren, Davis, & Hamill, 2007) while some investigations try to understand the differences in sex being it a main topic in the bibliography (Ferber, Davis, & Williams Iii, 2003; Sakaguchi et al., 2014). The aim of this study has been to analyse kinematic differences due to sex in recreational runners and due to performance level in male runners.

METHODS: A total of 48 runners participated in this study and were separated in female runners (n=12; age: 42,08±5,6 years; weight: 58,28±5,9 kg and height: 1,65±0,59 m), male amateur (n=38; age: 37,03±8,83 years; weight: 73.31±7,48 kg and height: 1,77±0,53 m) and male professionals (n=8; age: 26,38±6,25 years; weight: 63,86±4,61 kg and height: 1,74±0,48 m). A Vicon System composed of 6 infra-red cameras recording at 120 Hz and two Kistler piezoelectric platforms recording at 1000 Hz were used. 24 retro-reflective markers (18 for the dynamic capture) placed on the shoulder, pelvis, thigh, lower leg, and foot were placed in each subjects. The Plug & Gait Vicon Model was used and the lower body represented as a mechanical system of 4 solid rigids (pelvis, upper leg, lower leg and foot) each of them with six degrees of freedom. Running gait parameters and sagittal plane kinematics were recorded for each lower body joint and so was foot pronosupination. These variables are commonly used in the bibliography and they are part of a bigger project in which frontal and transversal were also recorded for these segments as well as forces. The subjects run on a synthetic floor indoor lane of 15 m. The times of foot-contact and foot-of were determined using the platforms. Recreational participants chose their own training speed while professional runners adapted the speed to the formers one. A three-way ANOVA was used to compare the three groups (recreational women, recreational men and professional men). As the sample sizes were different, the Levene Test for variance homogeneity was applied; if the test was significant, the Brown–Forsythe Test was applied. All the subjects were free of running related injuries at the time of the analysis and an approval from the University Ethical Committee was obtained.

RESULTS: The effect due to group was significant; therefore, a post-hoc comparison was carried out between sex in amateurs and between performance levels in men runners. The analysis of differences produced by the sex, showed that women had significantly slower speed ($p<0,005$) and shorter gait length both in meters and normalized with height ($p<0.005$) (Table 1). In the sagittal plane kinematics, the only significant difference was found for the hip extension at the foot-off instant ($p<0,005$) being smaller for women. There were no differences on the foot pronosupination between men and women recreational runners (Table 2).

Table 1
Running Gait parameters for the different groups

Variable	1. Women	2. Men Amateur	3. Men Elite	Differences	η^2
Gait Length/Height	1,14 (0,11)	1,31(0,13)	1,4(0,11)	**1*2 - 1*3**	0,325
Contact Phase %	38,47 (4,9)	36,2(3,58)	31,32(1,9)	**1*3 - 2*3**	0,247
Swing Phase %	61,53 (4,9)	63,8(3,58)	68,68(1,9)	**1*3 - 2*3**	0,247
Contact Phase (s)	0,28 (0,04)	0,27(0,03)	0,23(0,02)	**1*3 - 2*3**	0,197
Swing Phase (s)	0,45 (0,03)	0,47(0,03)	0,51(0,01)	**1*3 - 2*3 - 1*2**	0,278
Gait Frequency(Hz)	1,38 (0,07)	1,35(0,06)	1,35(0,05)		
Gait Length (m)	1,88 (0,18)	2,31(0,23)	2,49(0,15)	**1*2 - 1*3**	0,481
Speed (m/s)	2,59 (0,29)	3,12(0,33)	3,36 (0,27)	**1*2 - 1*3**	0,389

Mean (SD) for each variable and group. In bold significant differences (p<0,05).

The comparison of men in relation with performance showed that elite runners had significantly longer swing phase (in seconds) compared to the amateur runners ($p<0,005$) while no differences were found in gait frequency. Elite runners showed significantly greater knee flexion at the foot contact than the male amateur runners. These results are shown in Table 2.

Table 2
Sagittal (Hip, Knee & Ankle) & Frontal (Ankle) plane kinematics for the different groups

Variable	1. Women	2. Men Amateur	3. Men Elite	Differences	η^2
Hip Foot Contact(°)	46,66 (6,19)	42,13 (5,65)	39,96 (6,94)		
Hip Foot Off (°)	2,08 (5,02)	-4,75 (5,1)	-9,25 (7,41)	**1*2 - 1*3**	0,297
Hip Foot Off (°)	54,06 (4,97)	51,11 (6,9)	52,03 (6,31)		
Knee Foot Contact (°)	23,23 (5,52)	20,09 (6,37)	26,48 (4,65)	**2*3**	0,134
Knee Max. Flx. Contact (°)	52,88 (3,32)	49,67 (5,07)	53,94 (3,24)		
Knee Foot Off (°)	19,52 (4,76)	15,53 (5,45)	17,72 (2,6)		
Knee Max. Flx. Swing (°)	95,83 (6,65)	101,54 (10,92)	110,91 (7,8)	**1*3**	0,17
Ankle Flx. Foot Contact (°)	9,51 (6,09)	6,43 (6,34)	5,33 (5,86)		
Ankle Max. Flx. Contact (°)	27,8 (3,09)	27,19 (3,36)	28,89 (2,14)		
Ankle Flx. Foot Off (°)	-22,24 (9,67)	-25,2 (5,61)	-21,65 (4,46)		
Foot Supination Contact (°)	9,59 (5,31)	11,88 (7,37)	10,29 (7,42)		
Foot Max. Pronation (°)	-6,74 (4,83)	-5,29 (7,54)	-9,52 (7,12)		
Pronation Range (°)	-16,47 (2,92)	-17,14 (5,14)	-20,13 (3,67		

Mean (SD) for each variable and group. In bold significant differences (p<0,05).

DISCUSSION:

Comparison of recreational runners by sex. While cycle variables were clearly affected by the sex, sagittal kinematics were quite similar in male and women runners. This is in according with Sakaguchi et al. (2014), and Phinyomark, Osis, Hettinga, Leigh, and Ferber (2015), although Schache, Blanch, Rath, Wrigley, and Bennell (2003) found differences in running gait parameters but with the subjects running at a higher and at a given speed. The women selected a moderately lower speed (2.59 ±; 0.29 m/s) compared to men (3.12 ± 0.33 m/s, η= 0.4).

Analysing the cycle variables, one can see that women run slower because they had a smaller cycle length/height ratio (1.14 ± 0.11 m/m) than men (1.31 ± 0.13 m/m) while the cycle frequency was similar. Interestingly, the time of support and balance of the cycle were not affected by sex. This is in according with Ferber et al. (2003) and Sakaguchi et al. (2014). One of the most important findings is that kinematic variables were in general similar, however, the hip extension at the foot off was moderately higher (η= 0.3) in men (-4.75 ± 5.10º) than in women (2.08 ± 5.02º). The positive value of extension in women indicates that the thigh did not reach a real extension position in relation to pelvis. This can be affected by the pelvis position in relation with the horizontal with a bigger anterior tilting anteversión angle as it has been reported in women by Schache et al. (2003). It seems that women run with a smaller hip extension during foot release, which provoked a shorter cycle length. Interestingly, the initial supination and the maximum of pronation during the support phase were similar in women (9.59 ± 5.31º; -6.74 ± 4.83º) and men (11.88 ± 7.37º; -5.29 ± 7.74º) respectively. However, the variability was very high showing standard deviations between 5º and 8º.

Comparison between men based on performance. As expected there were no differences between the speed of recreational and professional runners, the frequency (1.35 Hz) and the cycle length/height ratio showed no significant differences. However, one can observe that professionals run with a cycle length/height ratio between 1.32 and 1.49 m/m (CI 95%) while amateurs move from 1.27 to 1.35 (CI 95%), that is, the difference was almost significant because the coefficients intervals overlapping was almost null. One must take the sample size of professional runners was small (n= 8) which produced a broader CI. On having simulated the CI with a bigger sample (n=20) the CI of 95% would be 1.35-1.45 m/m. That is, the tendency is that professionals have a longer stride length than amateurs. The only study found in the bibliography by the authors that analysed the same topic was Cavanagh, Pollock, and Landa (1977) and they did not find any differences between elite and non-elite runners in the running gait and sagittal kinematics parameters (except for the ankle) but their athletes run at a higher speed. Another important finding is that professionals ran with shorter (31.32 ±1.90 %) normalized support phase than amateurs (36.20 ±3.58 %). Only one significantly different variable amongst all the angular variables has been found showing that professionals reach the surface with the knee being more flexed (26.48 ±4.65º) than recreational runners (20.09 ±6.37º). This technical detail in the professional runners prove that they placed the foot bellow the centre of mass decreasing the breaking phase of support in this way; this is related with the reduction found in the support phase duration. Again, one has to remark that some variables as hip extension at foot off and maximal support foot pronation were not significant, possibly due to the reduced size sample professional. Professional runners extended the hip at foot release (-9.25 ± 7.41º) more than amateurs ((-4.75 ± 5.10º) which can be related with a longer cycle length. More research is need for understanding why the maximum support pronation is bigger (although not significant) in professionals (-9.52 ±7.12º) than in recreational runners (-5.29 ± 7.54º).

CONCLUSION:

Recreational women have shorter cycle length/height ratio and similar frequency compared to men produced possibly by a smaller hip extension angle at the foot off instant. The pelvis position could affect the hip flexion and extension angles so that in should be taken into consideration in a future analyses. That is, the sagittal kinematics and pronosupination are not affected by sex except for the hip extension in women in amateur runners is.
Recreational men runners seem to have shorter cycle length/height ratio and a bigger support phase time than professionals what is possibly related with some differences on sagittal kinematics as bigger hip extension and knee initial contact flexion. Interestingly, professional runners pronate the foot during the support phase more than amateurs.

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