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ORIGINAL RESEARCH

Customized footwear for motion control to treat anterior knee pain among runners

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BACKGROUND: Street running is extremely popular worldwide. Despite its benefits, there is evidence that stressful physical activity contributes to the development of lesions on the patellofemoral joint, leading, to anterior knee pain. As an attempt to attain pain control and to improve performance, specific footwear is being developed, aiming to suit particular types of foot strike, and therefore to reduce the risk of injury.
OBJECTIVE: To evaluate the effectiveness of the use of customized shoes, based on baropodometric test, for the remission of anterior knee pain among amateur street runners.
METHODS: This is a cross-sectional study, using questionnaires based on anthropometric and anatomical data of the runner, type of training, individualized footwear based on baropodometric test and diagnosis of anterior knee pain. In total, 40 athletes were studied, which were divided into two groups: Group 1, with 19 athletes who wore specific shoes for their activity, according to the type of foot strike, and, Group 2, with 21 athletes who used neutral shoes, not prescribed by healthcare professionals. All athletes practiced at the same running field.
RESULTS: Most of the athletes were female (70%), The pain remission had no overall statistically significant difference between the two groups. However, significant differences were found between groups A and B regarding the time of occurrence and the extent of AKP.
CONCLUSION: The data analysis showed that the use of customized running shoes, based exclusively on baropodometric exams, does not reduce anterior knee pain in amateur street runners, which is consistent with current literature. The improvement of pain with customized shoes, when present, appeared to have a short duration of around three month.

KEYWORDS: Running; Knee; Anterior Knee Pain Syndrome.

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INTRODUCTION

Street running is a sportive modality that is becoming increasingly more popular, worldwide: it has an easy public and low cost access.[1] It is a physical modality characterized by outdoors tracks, normally streets, in a variety of distances, and always very different from typical athletics tracks.[2] No longer exclusive domain of professional runners it became an activity mainly practiced by amateurs who seek a better quality of life through its benefits, both physical and mental.[3]

The widespread use of street running, in all social levels, raises doubts about the quality of information available to participants, in terms of how to conduct proper and safe procedures.[4]

Despite its obvious health benefits, there is some evidence that exhaustive and stressful physical activities, without proper orientation and incorrect practice, may induce musculoskeletal injuries,[5] most commonly affecting the knee joint. Patellofemoral pain syndrome (PFPS) is a frequently described comorbidity found and frequently is a consequence of training errors, lower extremity anatomical abnormalities, or wrong foot strike during gait. Typical of this condition, the most frequent patient complain is anterior knee pain (AKP).[6]

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Seeking improvements in sport performance, athletes are increasingly interested in the development of newer and more proper equipment, which might contribute to improved self-performance.[7] Running shoes experienced dramatic changes. The question then arises whether or not running shoes (sport shoes in general or specific cushioned running shoes), based on the most common gait kinematics (biomechanical measures related to the ground reaction forces and plantar pressures) have become popular among runners. A feature of footwear technology entitled 'motion control' aims to reduce excessive movements of the rearfoot during sports activities, and has been developed and used by runners.[8]

There are a number of running shoes seeking to meet most varieties of sports categories. However, based on recent studies, the type of shoes used to correct the running mechanics, by itself, have not proved to be enough to correct neuro-musculoskeletal and postural abnormalities as well as the anatomical axis deviation of lower extremities.[8]

The aim of this study is to evaluate the effectiveness of the use of individualized running shoes for the treatment of PFPS among street runners.

METHODS

This is an observational, descriptive, cross-sectional study. The study population consists of amateur runners of street racing clubs, which had already been asked to perform the baropodometric examination and who had indicated their use of custom-made running shoes, based on biomechanical measures related to the ground reaction forces and plantar pressures.

All patients had undergone evaluation for the presence of knee pain and lower limbs alignment at least six months prior to the beginning of the present study. A single orthopedic professional performed the clinical evaluations.

The studied sample consisted of 40 athletes divided into two groups according to the type of shoes worn: group A (n = 19) comprised runners who used cushioned customized running shoes and whose gait biomechanics (prone or supine) was identified by the baropodometric exam; group B (n = 21), included runners using neutral shoes with shock absorbers but not customized with specific cushioning.

Inclusion criteria were: (a) street runners, aged between 18 and 40 years; (b) presence of AKP during or after training; (c) over six months of experience. The exclusion criteria were: (a) runners without any episode of AKP, (b) AKP secondary to previous trauma or to healed fractures; (c) inflammatory diseases; (d) presence of varus or valgus alignment above 10 degrees; (e) a history of osteoarthritis or patellar dislocation; (f) Body Mass Index (BMI) above 30kg/m^2.

All included participants signed an informed consent form and the project was approved by the Institutional Research Ethics Committee, case number CAE 38426414.0.0000.5032 (November 26, 2014). Data collection was carried out between December 2014 and December 2015, in the running club linked to the orthopedic medical team responsible for the research.

Symptoms were evaluated as follows: the Visual Analogue Pain Scale (VAS); a level of satisfaction with the use of footwear; and a questionnaire based on the study of Taunton et al;[9] briefly, this contains questions related to the runners' data (age, sex, BMI), training characteristics (duration, frequency and type of terrain), the local and characteristics of AKP and footwear type and time of use. Another form was developed, to evaluate the period of pain remission in terms of: 1 – Complete improvement during and after 03 months; 2 – Partial improvement during and after 03 months; 3 – Return of symptoms after 03 months; 04 – No improvement of pain; 5 – Worsening of pain.

The data analyzes were conducted with the IBM software Statistical Package for Social Sciences (SPSS®, Chicago, IL, USA) 20.0 and the programming language and environment R36.

For descriptive analysis, quantitative variables were represented by mean and standard deviations when their distributions were normal, and interquartile ranges when not normal. Categorical variables were represented by frequencies and percentages.

Numerical variables were compared between groups using the "t" Student's test for normal distribution variables, and Man-Whitney test to non-normally distributed variables. Proportions were compared using the chi squared test or Fisher's exact test when necessary. The tests were performed with a significance level of 5%.

RESULTS

The 40 runners were divided into two groups: group A, with 19 runners who used cushioned customized running shoes (pronated or supinated) and group B with 21 runners who used neutral shoes.

All runners ran on flat asphalt tracks.

Table 1 shows the results for the general data of the runner (gender, age and BMI) and data about the lower limbs alignment.

Most runners in both groups were female (70% overall), being 73.7% in group A and 66.7% in group B, respectively. Age (in years) is represented by medians and interquartile intervals: the most prevalent age was 22 in group A and 25 in group B. The predominant BMI (also represented by medians and interquartile intervals) was 23kg/m^2 in both groups and in the complete sample.

As also shown in Table 1, the alignment of the lower extremities was evaluated: most runners, in both groups showed a valgus alignment of the knee, 3 to 5 degrees, while a minority in both groups presented with a knee varus alignment from 0 to 5 degrees.

Table 1 – Sex, age, BMI and lower limb alignment in street runners group

Characteristics	General (n = 40)	Group A (n = 19)	Group B (n = 21)	p Value
Sex				
Female	28.0 (70.0)	14.0 (73.7)	14.0 (66.7)	0.736[a]
Male	12.0 (30.0)	5.0 (26.3)	7.0 (33.3)	
Age	25	22	25	0.265[c]
Median (Interquartile Range)	(20.3 - 31.0)	(19.5 - 30.5)	(22.0 - 31.0)	
BMI	23	23	23	0.912[c]
Median (Interquartile Range)	(22.0 - 24.0)	(21.5 - 24.0)	(22.0 - 24.0)	
Lower Limbs Alignment				
Valgus (3 to 5 degrees)	27.0 (67.5)	15.0 (78.9)	12.0 (57.1)	0.186[a]
Varus (0 to 5 degrees)	13.0 (32.5)	4.0 (21.1)	9.0 (42.9)	

All data are presented as n (%), except if specified. [a] χ^2 Test; [c] Mann-Whitney U Test.

In table 2, we have data about the AKP of the street runners. In relation to the location of the AKP, most (62.5%) presented with bilateral pain; 22.5% had left knee, while 15% had right knee pain. In each group, the pattern was the same: In Group A, 63.2% had bilateral, 21.1% had left side and 15.8% had right side pain; in Group B, 61.9% had bilateral, 23.8% had left side and 14.3% had right side pain.

According to the VAS for pain, runners presented moderate pain intensity (05) for both groups and for the general population.

As also shown in Table 2, AKP occurred mostly during training, but without causing restriction (42.5%); in 35% of cases AKP occurred after training; in 12.5% of cases AKP was incapacitating for training; in 10%, AKP occurred during training and caused restrictions. Significant differences (P < 0.019) were found comparing groups A vs. B (different footwear). In group A, the most prevalent scenario was AKP during training without restrictions (52.6%), followed by AKP during practice, with restrictions (21.1%), AKP after training (15.8%) and disabling AKP (10.5%). In contrast, in group B, the majority presented AKP after training (52.4%), followed by AKP during practice and without restrictions (33.3%), incapacitating AKP (14.3%); AKP during training with restrictions did not occur.

In Table 3, we have the results of the use of footwear type among street running groups.

Regarding the current usage period of footwear (custom-made or neutral), results were similar with no significant differences for the general population and for each group (p = 0.379): the period of 6 to 18 months was the most prevalent, followed by a period of 3 to 6 months, then by 18 to 30 months, and more than 30 months.

Regarding the degree of satisfaction with the running shoes, 70% of the runners in general were satisfied or very satisfied, while 30% were dissatisfied or poorly satisfied. In group A and group B, most were also satisfied or very

Table 2 – AKP data, per street runners group, in 2014.

Characteristic	General (n = 40)	Group A (n = 19)	Group B (n = 21)	p Value
Affected Side				
Right	6,0 (15,0)	3,0 (15,8)	3,0 (14,3)	
Left	9,0 (22,5)	4,0 (21,1)	5,0 (23,8)	0,999[a]
Bilateral	25,0 (62,5)	12,0 (63,2)	13,0 (61,9)	
Visual Analog Scale	5 (4,0 - 5,0)	5 (4,0 - 5,0)	5 (4,0 - 5,0)	0,785[c]
Type of Pain				
After practice	14,0 (35,0)	3,0 (15,8)	11,0 (52,4)	
During, with no restrictions	17,0 (42,5)	10,0 (52,6)	7,0 (33,3)	0,019[b]
During, with restrictions	4,0 (10,0)	4,0 (21,1)	0,0 (0,0)	
Incapacitating pain	5,0 (12,5)	2,0 (10,5)	3,0 (14,3)	

All data are presented as n (%). a – χ^2 Test; b – Fisher's Exact Test; c - Mann-Whitney U Test

Table 3 – Footwear data, per street runners group, in 2014.

Characteristics	General (n = 40)	Group A (n = 19)	Group B (n = 21)	p Value
Type of footwear				
Neutral with shock absorber	21,0 (52,5)	0,0 (0,0)	21,0 (100,0)	
Pronated	7,0 (17,5)	7,0 (36,8)	0,0 (0,0)	-
Supinated	12,0 (30,0)	12,0 (63,2)	0,0 (0,0)	
Time using the footwear				
3 to 6 months	7,0 (17,5)	5,0 (26,3)	2,0 (9,5)	
6 to 18 months	22,0 (55,0)	8,0 (42,1)	14,0 (66,7)	0,379[b]
18 to 30 months	6,0 (15,0)	3,0 (15,8)	3,0 (14,3)	
More than 30 months	5,0 (12,5)	3,0 (15,8)	2,0 (9,5)	
Footwear Usage Satisfaction Degree				
Unsatisfied	3,0 (7,5)	1,0 (5,3)	2,0 (9,5)	
Poorly satisfied	9,0 (22,5)	6,0 (31,6)	3,0 (14,3)	0,547[a]
Satisfied	14,0 (35,0)	7,0 (36,8)	7,0 (33,3)	
Very satisfied	14,0 (35,0)	5,0 (26,3)	9,0 (42,9)	

[a] χ^2 Test; [b] Fisher's Exact Test

satisfied with the use of footwear (63.1% and 76.2%, respectively), with no significant statistical difference for footwear type satisfaction (p = 0.547).

In Table 4, we have the results for the type of training that the runners practiced per group along 2014.

Training duration was similar in both groups: there was a predominance of 2 to 3 hour of daily training (approximately 60% of cases), followed by 1 to 2 hour per day and more than 3 hours per day.

In table 5, regarding the period of pain remission, most runners, had a partial improvement of AKP during and after 3 months, followed by runners who did not have improvement, then by runners who fully improved pain during and after three months and then by athletes who had recurrence of symptoms after 3 months. The least occurrence was of runners who had a worsening of AKP. There was no statistical significance of pain remission period with the type of footwear used (p = 0.816).

DISCUSSION

Among street runners there is a high prevalence rate of patellofemoral pain syndrome (PFPS). AKP was more prevalent in females, and in the age group of 20 to 31 years old. Among all the studied variables, only the caracteristics of pain showed a relation with the shoe models, being more frequent during running in people using customized footwear for motion control based on baropodometric exam; AKP was also more prevalent after training in runners using neutral shoes with only rear shock absorbers.

It is known that the type of terrains can interfere in lesion occurrence and PFPS in street runners; the type of training can also interfere, according to his/her capacity.[10] Thus, participants were selected within a tight range of training timing and training intensity, based on the Tauton et al. questionnaire.[9] Attempts to predict who is more likely to develop pain is not easy, because the pathology has many possible causes. Therefore, there is no proven method to collectively prevent AKP in amateur street runners. The most affected population is female, young and physically active.[11]

Runners who wore custom-made running shoes reported pain during training and most runners with neutral footwear reported pain mostly after training.[9] Current running shoe models are constructed with damping and some higher calcaneus support, which reduces the magnitude and rate of the vertical loading during the gait, probably reducing discomfort during contact of lower limbs with the ground.[12]

Among the runners with foot orthosis, most had a foot pronation gait pattern. Excessive pronation is an etiological factor in developing injury among runners.[13] Our research demonstrated that most athletes who complain of AKP, run an average of 3-5 days in a week, during 2 to 3 hours for each workout. There is evidence indicating that the increase in the number of days of training and run distance per week are predictors of lower extremities injuries.[14]

Some studies explored the treatment for PFPS controlling foot movements with the use of foot orthoses.[8] However, in our study, the remission of AKP, indicated no statistically significant difference for the type of footwear used during running practice, suggesting that the type of footwear, by itself, wouldn't interfere in the reduction of PFPS.[15–17] Some studies also explicit that running barefoot provides less stress on the patellofemoral joint when

Table 4 – Type of training data per street runners group.

Characteristics	General (n = 40)	Group A (n = 19)	Group B (n = 21)	p Value
Training duration				
1 to 2 hours	8.0 (20.0)	3.0 (15.8)	5.0 (23.8)	
2 to 3 hours	25.0 (62.5)	13.0 (68.4)	12.0 (57.1)	0.820[a]
More than 3 hours	7.0 (17.5)	3.0 (15.8)	4.0 (19.0)	
Weekly training frequency				
2 workouts	4.0 (10.0)	2.0 (10.5)	2.0 (9.5)	
3 workouts	15.0 (37.5)	8.0 (42.1)	7.0 (33.3)	0.946[a]
4 workouts	2.0 (5.0)	1.0 (5.3)	1.0 (4.8)	
5 workouts	19.0 (47.5)	8.0 (42.1)	11.0 (52.4)	

[a] χ^2 Test

Table 5 – Pain remission period per street runners group.

Remission Period	General (n = 40)	Group A (n = 19)	Group B (n = 21)	p Value
Full recover during and after 3 months	5 (12.5)	3 (15.8)	2 (9.5)	
Partial improvement after 3 months	20 (50.0)	8 (42.1)	12 (57.1)	
Recurrence of symptoms after 3 months	5 (12.5)	3 (15.8)	2 (9.5)	0.816[b]
No pain relief	9 (22.5)	5 (26.3)	4 (19.0)	
Pain worsening	1 (2.5)	0 (0.0)	1 (4.8)	

[b] Fisher's Exact Test

compared to running with footwear and consequently a lower level of damage.[12,17]

We observed significant prevalence of lesions in street runners, even analyzing in the short period of six months. The negative consequences of the injuries can affect the athlete's psychological health and induce unfavorable feelings toward the sportive modality.[18]

We wish to assert the importance of an adequate training program and physiotherapy focusing on the lower limb strengthening to treat AKP, instead of a treatment based on footwear for motion control as a single factor. This study shows new data based on AKP among athletes, relating to footwear, using a adapted questionnaire. This study is part of our general project on AKP.[19]

A limitation of our study was the small sample size, which did not allow for the performance of multivariate analyzes to certify the weight of each variable in the event of injury. Randomized control trials should be performed, comparing each foot orthosis and cushioning, as well as the instruments to evaluate the lower limb posture and gait. This study was conducted in a specific running club and a specific population, which could cause a selection bias. Further research is required to examine the relationship between shoes, PFJ stress and pain in runners.

According to this study, and similar biomechanical studies on the concern customized running shoes for motion control in the management of AKP, it is recommended prior to start practicing street running, to get orthopedic assessment in order to detect the necessity of lower limb kinesiotherapic postural correction with an emphasis on dynamic valgus and strengthening of involved muscles of the tie, hip and leg.[20,21]

In order to justify the use of motion control shoes in the management of PFPS, more evidence needs to be established with further clinical and biomechanical studies.[8]

CONCLUSION

Based on these results, no statistically significant difference among customized footwear for motion control, based on baropodometric exams, used to improve anterior knee pain among amateur street runners. However, significant differences were found between groups A and B regarding the time of occurrence and the extent of AKP. Most runners with pain were female, and improvement with customized shoes seems to have a short duration of around three month. Further research is required to examine the relationship between footwear, PFJ stress and pain in runners.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding this project.

AUTHOR PARTICIPATION

David Sadigursky revised the manuscript and contributed to the conception of the project; together with Natallia Andrade Mota Santos wrote the manuscript and revised the literature; Gustavo Castro de Queiroz, Leandro Oliveira and Marcio Pinheiro de Souza collected the data in the running club and the clinical data of participants; they also performed the statistical analysis Rogério Jamil Fernandes Carneiro and Paulo Oliveira Colavolpe revised the manuscript and contributed to the conception of the project.

CALÇADO PERSONALIZADO PARA CONTROLE DE MOVIMENTO PARA TRATAR A DOR ANTERIOR DO JOELHO ENTRE OS CORREDORES

FUNDAMENTO: Corrida de rua é extremamente popular em todo o mundo. Apesar dos seus benefícios, há evidências de que o estresse dessa atividade física contribui para o desenvolvimento de lesões da articulação patelofemoral, levando, à dor anterior do joelho. Como uma tentativa de alcançar o controle da dor e para melhorar o desempenho, calçados específicos foram desenvolvidos, visando adequar determinados tipos de impacto do pé, e, por conseguinte, para reduzir o risco de lesões.

OBJETIVO: Avaliar a eficácia do uso de sapatos personalizados, com base no teste de baropodometria, para a remissão de dor anterior do joelho entre os corredores de rua amadores.

MÉTODOS: Este é um estudo transversal, por meio de questionários com base nos dados antropométricos e anatômicas do corredor, tipo de treinamento, calçado individualizado com base no teste de baropodometria e diagnóstico da dor anterior do joelho. No total, 40 atletas foram estudados, divididos em dois grupos: Grupo 1, com 19 atletas que usavam sapatos específicos para a sua atividade, de acordo com o tipo de ataque de movimento do pé, e, Grupo 2, com 21 atletas que usaram sapatos neutros, não prescritos por profissionais de saúde. Todos os atletas treinaram em um mesmo campo.

RESULTADOS: A maioria dos atletas eram do sexo feminino (70%); não houve diferença estatisticamente significativa entre os dois grupos em termos de remissão da dor.

CONCLUSÃO: A análise dos dados mostrou que o uso de tênis personalizados, com base exclusivamente em exames baropodométricos, dor anterior do joelho não reduz a dor os corredores de rua amadores, o que é consistente com a literatura atual. A melhora da dor com sapatos personalizados parece ter uma curta duração de cerca de três meses.

PALAVRAS-CHAVE: Corrida; joelho; Síndrome de dor anterior do joelho

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