

# Risk factors for overuse injuries in runners' ankles: a literature review

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**INTRODUCTION:** In spite of the numerous benefits to human health and given the increase of running as an exercise that has become popular worldwide, this type of sport may be the cause of a number of different injuries. The foot, ankle and lower leg comprise almost 40% of the injuries. However, the etiology of these types of injury is still not completely understood.

**OBJECTIVE:** To investigate the causes of the onset of overuse injury in runners.

**METHODS:** A systematic search of the electronic database was made: Bireme, Pubmed and PEDro, which were selected that addressed clinical trials, control cases, prospective and cross-sectional studies.

**RESULTS:** The search through the descriptors yielded 324 references. Using our predefined inclusion criteria (case studies, clinical trials, prospective studies and cross studies that addressed adult runners, amateur or professional) 68 articles remained; 24 citations were excluded after reading the title, and 35 were excluded after reading the abstract and the full text. Therefore nine studies that met the criteria for analysis were included.

**CONCLUSION:** The etiology of overuse injuries in runners is multifactorial. This review showed that distance, soil type and footwear, as well as a history of previous injuries, biomechanical changes such as increased dorsiflexion and eversion ankle, and greater knee flexion are risk factors that influence the occurrence of these injuries.

**KEYWORDS:** Ankle; Overuse; Running.

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## INTRODUCTION

The number of people who practice running has increased in the last three decades.<sup>1,2</sup> in parallel with a general increase of physical activity. Running is one of the most popular sports and statistics show significant growth in recent years.<sup>3</sup> In spite of its positive effects on health and well-being, there are also injuries related to it.<sup>1,4</sup>

According Taunton et al.<sup>2</sup> a in study with more than 2,000 individuals who attributed their injuries to running, the knee is the point of higher incidence. The foot, the ankle and the lower leg comprise almost 40% of the remaining injury, while less than 20% of the reported injuries occur above the knee. Lesions are mainly the result repeated low intensity mechanical overloads and this is the context that characterizes overuse injuries.<sup>2,5</sup>

Research shows that the most common sites of overuse injuries are legs, ankles and feet. Among these, the ankle<sup>6-10</sup> is the structure where the main types of overuse injuries are observed: stress fracture, tendinitis calcaneus, chronic compartment effort syndrome and medial tibial stress syndrome.<sup>5,11</sup>

Overuse injuries have a multifactorial etiology and the contributing factors may be intrinsic or extrinsic.<sup>12-15</sup> Intrinsic factors are demographic (age, gender and race), anatomical (dysmetry, high arch of the foot and valgus knee) and biomechanical (mineral density and bone geometry).<sup>16-24</sup> Extrinsic factors refer to the characteristics of the training: volume, intensity and frequency, environment and shoes.<sup>3,25</sup>

Because of the varied nature of the causes of these injuries and due to the need to constantly improve rehabilitation and prevention, the objective of this study was to conduct a review of risk factors associated with overuse injuries in runners' ankles.

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## METHODS

This study was developed at the Laboratory of Movement Study, Institute of Orthopedics and Traumatology, Faculty of Medicine, University of São Paulo, Brazil.

### Inclusion criteria

The inclusion criteria were case studies, clinical trials, prospective and cross-sectional studies that addressed adult runners (18-44 years old), amateur or professional. The included studies had biomechanical and risk factors evaluation in subjects with a history of overuse injury to the ankle, published over the last 10 years, in English. We excluded studies that addressed disorders that were not overuse injuries in runners. Review articles and case reports were also excluded.

### Research strategy

The literature review was carried out in the following electronic databases: Bireme (Regional Medical Library), PubMed (U.S. National Library of Medicine and the National Institutes of Health) and PEDro (Physiotherapy Evidence Database). The search aimed to find articles published on overuse injuries in runners' ankles, with the following scientific descriptors: overuse injuries, ankle and running.

### Review process

Two researchers (NFBA and NMSL) independently conducted the review process. After the pre-selection of articles, titles and abstracts were read to check for compliance to the objectives. The references were selected by reading the titles and abstracts independently, and by creating a single list of all the articles to be included into, or excluded from the study. In case of doubt, the complete text was read. After this stage, the inclusion or not of the articles was decided. The search through the descriptors totaled 324 references. Using the inclusion criteria, 68 studies remained. We excluded 24 citations after reading the title, and 35 after reading the abstract and the full text, leaving therefore nine studies that met the analysis criteria. A third examiner (ACC) inspected the data in quest for any disagreement between the two primary researchers.<sup>26</sup>

## RESULTS

Table 1 presents the results of the primary search. Once the complete articles were acquired and the complete reading of those studies was evaluated, nine studies were eligible for review, as illustrated by the flow chart in Figure 1.

The selected studies were analyzed and data extraction was carried out as the sample characterization, details of the assessment or intervention and conclusion. The year of publication of the articles was from 2004 to 2012 and the sample size ranged 22-1004 subjects. All articles were clinical trials, including a prospective cohort

**Table 1** - Articles detected with each keyword or Boolean set of keywords located in each of the databases

Keywords	PUBMED	BIREME	PEDro
Ankle	48,152	44,108	1,196
Injuries	806,053	563,246	672
Running	45,815	45,584	234
Overuse	5,574	9,465	57
Ankle AND injuries	14,589	13,108	142
Running AND injuries	3,560	3,134	28
running AND overuse	294	421	7
Injuries AND ankle	14,589	13,108	142
Injuries AND overuse	1,983	3,345	27
running AND injuries AND ankle	400	353	12
overuse AND injuries AND ankle	287	337	14
overuse AND injuries AND running	271	340	4
Articles with potential for inclusion in the study	291	26	7

study. Of the nine studies selected, seven included a control group, and six compared subjects with and without injury; in one study all participants had a history of injury and were divided into two groups, one using bracing, one not (group control).

The most recent study investigated overuse injuries in running and associated factors through a questionnaire.<sup>27</sup> Two studies assessed the activation of ankle muscles during running using electromyography.<sup>28,29</sup> Four studies consisted of kinematic analysis performed by a three-dimensional camera system<sup>30-33</sup> whereas a single study included a kinetic analysis performed on a force platform.<sup>33</sup> One study used an electronic platform system for assessment of foot type (Novel Electronics Munich, Germany);<sup>34</sup> and finally, one study measured the alignment of the lower limbs through measuring devices (tape and goniometer).<sup>35</sup>

Achilles tendinopathy was the most discussed injury, appearing in four articles<sup>29-32</sup>, followed by stress fracture (one study)<sup>33</sup>. However, the other four articles included various overuse injuries in the lower limbs.<sup>27,28,34,35</sup>

The manner of evaluation during running varied widely. In two studies individuals were evaluated running with standardized neutral shoes.<sup>29,33</sup> In the study by Lun et al.<sup>35</sup> participants wore their usual running shoes. In the Donoghue et al.<sup>32</sup> study, participants either wore shoes or ran barefoot; in Ryan et al.<sup>30</sup> all runners ran barefoot. In the other Donoghue et al. study<sup>31</sup> athletes used their own shoes and were evaluated with and without orthosis; in the Baur et al. study,<sup>28</sup> the test group used orthosis and the control group did not; in the Nakhaee et al. study<sup>34</sup> athletes were evaluated during free gait.

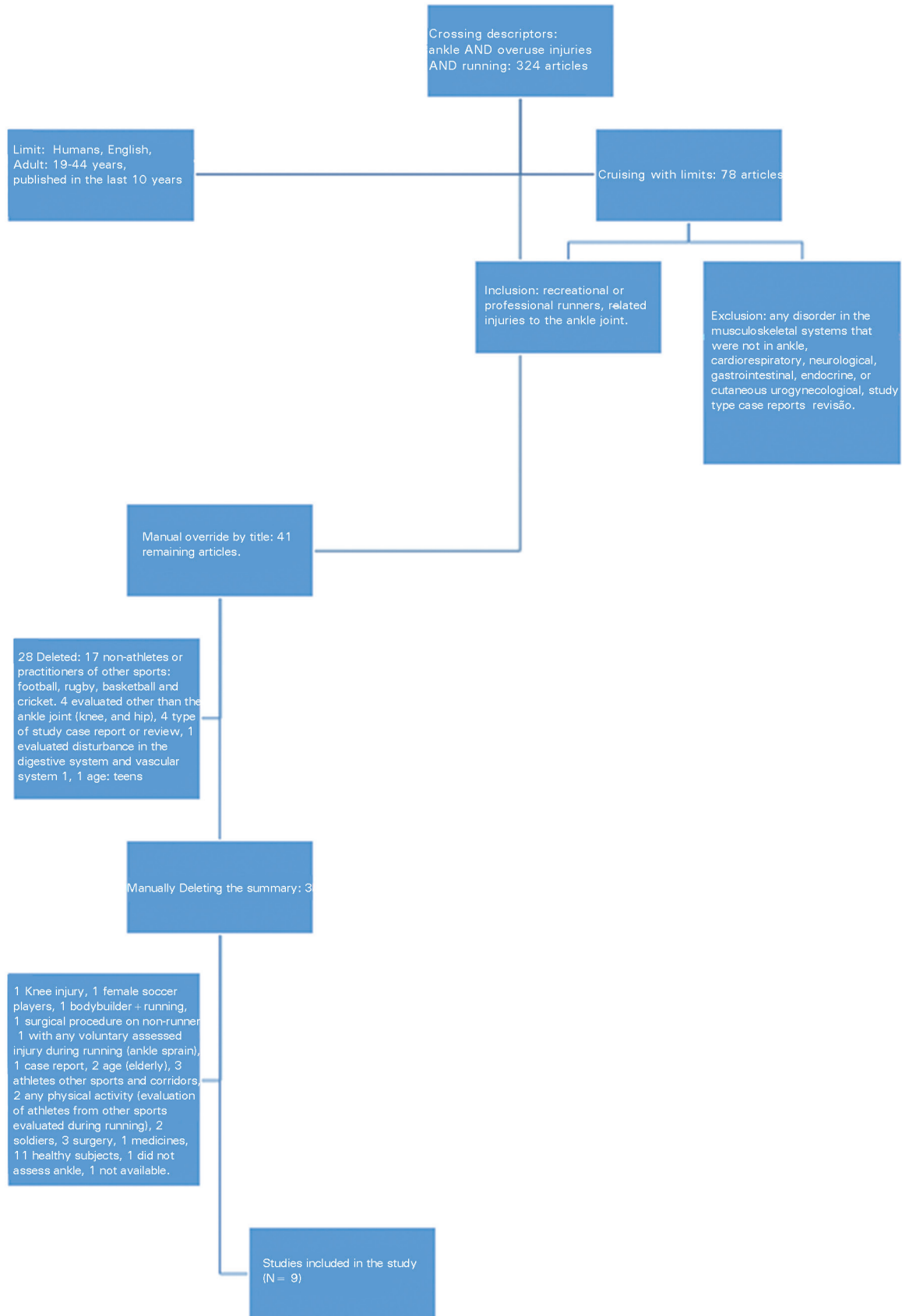


Figure 1 - Flow chart of study selection.

Two studies used only male subjects,<sup>30,34</sup> whereas Milner et al.<sup>33</sup> studied females. In six studies, men and women participated.<sup>27-29,31,32,35</sup> In three trials, subjects were runners with running distances greater than 32 km/week;<sup>28,29,33</sup> in one study (Ryan et al.<sup>30</sup>) all volunteers ran at least 30 km per week; in the Lun et al. study<sup>35</sup> athletes ran at least 20 km/week; the Chung et al. study<sup>27</sup> included runners who participated in races of 10, 21 and 42 km; Nakhaee et al.<sup>34</sup> evaluated professional runners training 2 hours 3 times a week; two studies<sup>31,32</sup> did not mention the type of training, but state that all subjects were involved in racing or in sports where running was the main element, and included control group subjects recruited from running clubs.<sup>31,32</sup>

Table 2 shows the main features found in nine studies analyzed in this study.

## ■ DISCUSSION

The evaluation of factors associated with overuse injuries in runners' ankles had very different objective and methodological approaches in the various studies included in this review; no two articles came up with the same proposal. They diverge mainly in the study population, group choices, evaluation methods, and injury types.

A systematic review study highlighted the differences between athletes with or without calcaneus tendinopathy with respect to the biomechanical profile of their lower limbs during running; the most significant difference was the eversion of the subtalar joint.<sup>36</sup> This point was corroborated in all the selected studies which did perform a kinematic analysis.<sup>30-32</sup> Individuals who used shoes showed greater eversion values than those who ran barefoot.<sup>32</sup> The comparison of individuals running with and without the use of orthoses agreed with previous data on eversion, ankle dorsiflexion and knee flexion in subjects with Achilles tendinopathy: orthoses reduced dorsiflexion, but increased eversion.<sup>31</sup>

In individuals with no history of lesions, Wiegerink et al.<sup>37</sup> detected differences with respect to pressure peak, maximal force and contact area when comparing runners wearing two different shoe types; they concluded that these differences may be important when one considers the influence of shoe type upon the occurrence of stress fractures in runners, generally.

Two studies by Baur et al.<sup>28,29</sup> were eligible for selection. They analyzed the neuromuscular activity by electromyography (EMG), in different situations. One study compared the neuromuscular activity among runners with Achilles tendinopathy vs. healthy subjects;<sup>29</sup> and the other observed the activation of the peroneus longus muscle before and after eight weeks of use of bracing, in runners with symptoms of overuse injury.<sup>28</sup>

In the first study, there was less activation of the peroneal muscle during weight bearing in patients with

calcaneus tendinopathy when compared to controls. But no differences were found in the pre-activation and push-off, nor in the average of the gastrocnemius amplitude values. Thus, the authors concluded that calcaneus tendinopathy does not seem to change the preprogrammed neural control, but can induce mechanical deficits, loss of strength and ligament looseness in the lower limbs during weight bearing, thus affecting articular stability.

In the second study, in a pre-activation condition, muscle activity was higher in subjects who used the bracing after the intervention. However, the authors conclude that the increased muscular activity of the peroneus longus muscle in pre-activation suggests a pre-programmed activity that can lead to better stability of the ankle, providing a possible mode of action for foot orthoses therapy.<sup>28</sup>

Other studies show that the use of footwear and orthoses does not reduce lesions in soft tissue after intense running,<sup>38</sup> nor injuries and stress-related lower limb overuse lesions;<sup>39</sup> This includes a study on the use of bracing in runners with increasing rates of pain in knees and ankles.<sup>27</sup> However, the evidence base is not strong enough, because the number of trials is small and the bias risk high.<sup>38</sup>

Stress fractures are common and serious overuse injuries in runners, especially in female runners. The tibia is the most common site with incidence rates of up to 20%.<sup>33</sup> They may be related to the lower end load characteristics during running.<sup>40-42</sup> One of the articles included in this study<sup>33</sup> evaluated runners who suffered tibial stress fracture and noted the significant increase of the vertical force and shock on the tibia, showing the relationship between the history of the injury and the increase in dynamic load variables.

Although some articles enumerate poor alignment as an intrinsic factor related to overuse injuries,<sup>2,11,43,44</sup> Lun et al.<sup>35</sup> demonstrated that there is no evidence that the measures of static biomechanical alignment are related to lesions in lower limb runners, except in knee injuries (patellofemoral syndrome), in agreement with other studies investigating precisely this variable.<sup>45-47</sup>

Little is known about the influence of the height of the longitudinal arch of the foot in overuse injuries in runners. Williams et al.<sup>48</sup> in a prospective study concluded that the structure of the high or low arch is related to different types of injuries in runners. In opposition, Nakhaee et al.<sup>34</sup> studied the height of the medial longitudinal arch, peak force, peak pressure and the contact area of the foot in static and dynamic conditions, comparing healthy runners and runners with overuse injuries; they pointed out that the height of the longitudinal arch of the foot not is a risk factor for sport injuries. These reports corroborate other studies suggesting that associated factors such as type of footwear, areas of training, injury history, and distance traveled weekly<sup>3,49</sup> can determine the likelihood of injury,<sup>11,34</sup>

**Table 2** - Studies evaluating the etiology of ankle injuries

Running injuries and associated factors in participants of ING Taipei Marathon (Chang et al. 2012) <sup>27</sup>	1,004 runners in the ING Taipei International Marathon	Questionnaire completed 3 days before the event including: personal characteristics, health status, previous race injury sites, training routine details, shoes and orthoses types used.	Orthosis in knee and ankle was associated with increased pain rate in knee and ankle. Group members who ran the full marathon, who practiced in synthetic track had a higher incidence of pain in the ankle.
Neuromuscular activity of the peroneal muscle after foot orthoses therapy in runners (Baur et al. 2011) <sup>28</sup>	99 runners with symptoms of overuse injury (control x bracing)	Neuromuscular activity of the peroneus longus muscle after 8 weeks of treatment with orthoses	The activation of the peroneus longus muscle suggests a preprogrammed altered activity, which may lead to a better stability of the ankle providing a possible mode of action for the foot orthotic therapy.
Comparison in lower leg neuromuscular activity between runners with unilateral mid-portion Achilles tendinopathy and healthy individuals. (Baur et al. 2011) <sup>29</sup>	60 runners (30 control x 30 with Achilles tendinopathy)	Neuromuscular activity of the leg (tibialis anterior, gastrocnemius and peroneus) during running.	The tendinopathy of the Achilles does not seem to change the preprogrammed neural control, but can induce mechanical deficits of the lower limbs during weight bearing (joint stability).
Kinematic analysis of runners with achilles mid-portion tendinopathy (Ryan et al. 2009) <sup>30</sup>	48 runners men (27 with pain in Achilles tendon and 21 asymptomatic subjects - control)	Kinematic analysis (dimensional motion system)	Increased eversion of the subtalar joint runners with Achilles tendinopathy, which had hyperpronation during the stance phase of running.
Functional data analysis of running kinematics in chronic Achilles tendon injury (Donoghue et al. 2008) <sup>31</sup>	24 runners (12 with Achilles tendinopathy x 12 without lesions in the lower limbs)	Three-dimensional kinematic analysis (camera system)	Subjects with Achilles tendinopathy showed increased eversion, ankle dorsiflexion and knee flexion. Using bracing was reduced dorsiflexion, but increased eversion. The study showed evidence that the variability is related to the presence of lesions in this clinical population.
Lower limb kinematics of subjects with chronic achilles tendon injury during running (Donoghue et al. 2008) <sup>32</sup>	22 subjects runners (11 controls x 11 with calcaneus tendinopathy history)	Three-dimensional kinematic analysis (camera system)	The data revealed qualitative differences in the angle-time curves between calcaneus tendinopathy group and control during running with and without shoes. Subjects with tendinopathy showed higher eversion and dorsiflexion of the ankle, and lower leg abduction during the laying, compared to the control.
Biomechanical factors associated with tibial stress fracture in female runners (Milner et al. 2006) <sup>33</sup>	40 long-distance runners (20 with a history of stress fracture of tibia x 20 without lesions in the lower limbs)	Kinematic and kinetic analysis (cameras and force plate system)	The tibial stress fracture history runners is associated with increased variables related to dynamic loads.
The relationship between the height of the medial longitudinal arch (MLA) and the ankle and knee injuries in professional runners (Nakhaee et al. 2008) <sup>34</sup>	47 men professional runners (30 control x 17 with historical damage in ankle/knee)	Test "Navicular Drop" Emed pedograph platform system (Novel Electronics, Munich, Germany) to assess the height of the medial longitudinal arch. After this evaluation, compared individuals who have had injury or not.	Have normal longitudinal arch, more or less can not be defined as a risk factor for injuries related to sports.
Relation between running injury and static lower limb alignment in recreational runners (Lun et al. 2004) <sup>35</sup>	87 amateur runners healthy	Measurement of static alignment of the lower limbs related to injuries sustained during six months of monitoring	There is no evidence that the measures of static biomechanical alignment are related to lesions in the lower limbs runners, except patello-femoral syndrome.

whereas improper changes in duration, frequency or "training errors" are the most common causes of overuse injuries in recreational athletes.<sup>50</sup>

## ■ CONCLUSION

The etiology of overuse injuries in runners is multifactorial. This review shows that distance, soil type, footwear and history of previous injuries, apart from biomechanical alterations, such as increased dorsiflexion and eversion ankle, as well as knee alterations (greater flexion) are risk factors that influence the occurrence of these injuries. It must however be stressed that published reports on this problem are few and biasridden, on account of lack of uniformity, in terms of the evaluation techniques and in terms of targeted populations.

## FATORES DE RISCO PARA LESÕES DE ESFORÇO EM TORNOZELOS DE CORREDORES: REVISÃO DA LITERATURA

**INTRODUÇÃO:** Apesar dos inúmeros benefícios para a saúde humana e considerando o aumento da corrida como exercício, atividade mundialmente popular, este tipo de esporte pode ser a causa de uma série de diferentes lesões. O pé, tornozelo e parte inferior da perna compreendem quase 40% das lesões. No entanto, a etiologia destas lesões permanece mal compreendida.

**OBJETIVO:** investigar as causas do aparecimento da lesão de esforço em corredores.

**MÉTODOS:** Uma busca sistemática foi realizada nas seguintes bases de dados: Bireme, PubMed e PEDro, selecionando-se ensaios clínicos, casos controle, estudos prospectivos e de corte transversal.

**RESULTADOS:** A pesquisa através dos descritores rendeu 324 referências. Usando critérios de inclusão pré-definidos (estudos de casos, ensaios clínicos, estudos prospectivos e estudos transversais que abordavam adultos corredores indivíduos, amador ou profissional) permaneceram 68 artigos; 24 citações foram excluídos depois de ler o título, e 35 foram excluídos após a leitura do resumo e do texto integral. Portanto nove estudos que preencheram os critérios de análise foram incluídos.

**CONCLUSÃO:** A etiologia das lesões de esforço em corredores é multifatorial. Esta revisão mostrou que a distância, tipo de solo e calçados, bem como uma história de lesões prévias, alterações biomecânicas como o aumento da dorsiflexão e eversão do tornozelo, e uma maior flexão do joelho são fatores de risco que influenciam a ocorrência dessas lesões.

**UNITERMOS:** Tornozelo, Uso excessivo, Lesões de esforço, Corredores.

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