EFFECT OF SPORTS FATIGUE ON PLANTAR PRESSURE DISTRIBUTION OF HEALTHY MALE COLLEGE STUDENTS

EFEITO DA FADIGA ESPORTIVA NA DISTRIBUIÇÃO DA PRESSÃO PLANTAR DE ESTUDANTES UNIVERSITÁRIOS MASCULINOS SAUDÁVEIS

EFECTO DE LA FATIGA DEPORTIVA SOBRE LA DISTRIBUCIÓN DE LA PRESIÓN PLANTAR EN ESTUDIANTES UNIVERSITARIOS MASCULINOS SALUDABLES

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ABSTRACT

Objective: To understand the influence of sports fatigue on plantar pressure distribution of healthy male college students and provide a theoretical basis for improving their awareness of foot health. Methods: Forty-nine ordinary male college students jogged along the 800-meter runway to moderate fatigue. All the subjects took off their shoes and socks and walked naturally with their usual gait. The dynamic plantar pressure of each foot was measured twice in one step. FootscanUSB2 Belgian flat-plate plantar pressure testing system was used for testing. Results: The average dynamic peak plantar pressure was (206.38 44.59) N for boys, and the changes of AA and CB walking speed in the arch did not change significantly. After fatigue, the peak pressure of FM, AA, RH5 in left foot and FM, AA, CB in right foot decreased significantly ($P < 0.05$, $P < 0.01$). The peak time of RH and CB in the left foot was significantly shorter than that before fatigue ($P < 0.05$, $P < 0.01$), while FMF, AA, C areas had no significant change but tended to be delayed. There were significant differences in peak force-time between boys' left and right feet except for the fifth metatarsal bone ($P < 0.05$). There is a significant difference in the peak force-time between the second and fifth toes of the left foot ($P< 0.01$), and there is a gender difference in the peak force-time between the second metatarsal and the third metatarsal ($P < 0.05$). Conclusion: Sports fatigue leads to the decrease of physiological functions such as muscle strength of lower limbs, which leads to the corresponding changes in gait stages, plantar pressure distribution parameters, and foot balance. ***Level of evidence II; Therapeutic studies - investigation of treatment results***.

Keywords: Athletic Injury; Foot Injury; Pressure Sore.

RESUMO

Objetivo: Entender a influência da fadiga esportiva na distribuição da pressão plantar de estudantes universitários masculinos saudáveis e fornecer uma base teórica para melhorar sua consciência sobre a saúde dos pés. Método: Quarenta e nove estudantes universitários masculinos comuns correram ao longo da pista de 800 metros para moderar a fadiga. Todos os sujeitos tiraram seus sapatos e meias e caminharam naturalmente com sua marcha habitual. A pressão plantar dinâmica de cada pé foi medida duas vezes em um único passo. O sistema de teste de pressão plantar de placa plana belga FootscanUSB2 foi usado para testes. Resultados: A pressão plantar dinâmica média de pico foi (206.38 44.59) N para meninos, e as alterações de velocidade de caminhada AA e CB no arco não mudaram significativamente. Após a fadiga, a pressão de pico de FM, AA, RH5 no pé esquerdo e FM, AA, CB no pé direito diminuiu significativamente ($P < 0,05$, $P < 0,01$). O tempo de pico de RH e CB no pé esquerdo foi significativamente menor do que antes da fadiga ($P < 0,05$, $P < 0,01$), enquanto as áreas FMF, AA, C não tiveram nenhuma mudança significativa, mas tenderam a ser atrasadas. Havia diferenças significativas no tempo de pico de força entre o pé esquerdo e direito dos meninos, exceto para o quinto metatarso ($P < 0,05$). Houve uma diferença significativa no tempo de pico de força entre o segundo e o quinto dedos do pé esquerdo ($P< 0,01$), e há uma diferença de gênero no tempo de pico de força entre o segundo metatarso e o terceiro metatarso ($P < 0,05$). Conclusão: A fadiga esportiva leva à diminuição das funções fisiológicas, tais como a força muscular dos membros inferiores, o que leva às mudanças correspondentes nos estágios de marcha, parâmetros de distribuição da pressão plantar e equilíbrio do pé. ***Nível de evidência II; Estudos terapêuticos – investigação de resultados de tratamento***.

Descritores: *Lesões do Esporte; Traumatismos do Pé; Lesão por Pressão.*

RESUMEN

Objetivo: Comprender la influencia de la fatiga deportiva en la distribución de la presión plantar de los estudiantes universitarios varones sanos y proporcionar una base teórica para mejorar su conciencia sobre la salud de los pies. Métodos: Cuarenta y nueve estudiantes universitarios varones normales trotaron a lo largo de una pista de 800 metros hasta alcanzar una fatiga moderada. Todos los sujetos se quitaron los zapatos y los calcetines y caminaron de forma natural con su marcha habitual. Se midió la presión plantar dinámica de cada pie dos veces en un único paso. Para las pruebas se utilizó el sistema belga de pruebas de presión plantar FootscanUSB2. Resultados: El promedio de la presión plantar dinámica máxima fue de (206.38 44.59) N para los niños, y los cambios de la velocidad de marcha

AA y CB en el arco no cambiaron significativamente. Después de la fatiga, la presión máxima de FM, AA, RH5 en el pie izquierdo y de FM, AA, CB en el pie derecho disminuyó significativamente (P < 0,05, P < 0,01). El tiempo de pico de RH y CB en el pie izquierdo fue significativamente menor que antes de la fatiga (P < 0,05, P < 0,01), mientras que las áreas FMF, AA, C no tuvieron cambios significativos, pero tendieron a retrasarse. Hubo diferencias significativas en el pico de fuerza-tiempo entre los pies izquierdo y derecho de los niños, excepto en el quinto hueso metatarsiano (P < 0,05). Hay una diferencia significativa en el pico de fuerza-tiempo entre el segundo y el quinto dedo del pie izquierdo (P < 0,01), y hay una diferencia de género en el pico de fuerza-tiempo entre el segundo metatarsiano y el tercer metatarsiano (P < 0,05). Conclusión: La fatiga deportiva conduce a la disminución de funciones fisiológicas como la fuerza muscular de los miembros inferiores, lo que conlleva los correspondientes cambios en las fases de la marcha, los parámetros de distribución de la presión plantar y el equilibrio del pie. ***Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.***

Descriptores: *Lesiones en Atletas; Lesiones de los Pies; Llaga por Presión.*

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INTRODUCTION

The overall health of college students can not be ignored, but they may pay more attention to the improvement of physical fitness and the development of sports skills, but neglect their own foot health.[1] When walking, the pressure distribution between the sole and the supporting surface reflects the physiological, structural and functional information of the lower limbs and even the whole body. The trauma, deformity, tumor, infection, nervous system diseases and even mental state of the lower limbs will affect the gait of the human body to varying degrees.[1,2] Foot is an important part of the human body, and countless nerve endings are distributed in the foot, which are closely connected with the brain and closely related to human health, and are known as the "second heart".[3] Therefore, it is of great significance to maintain foot health.

Exercise-induced fatigue (hereinafter referred to as fatigue) refers to a phenomenon that the working ability of tissues and organs or even the whole body temporarily decreases after a period of exercise, and it is a common physiological phenomenon during exercise.[4] Because students don't know enough about ankle sprain, and the lesion is not obvious, it is difficult to heal after it happens. By detecting the distribution characteristics of plantar pressure of 49 male college students and investigating its influencing factors, the author discusses the foot health of male college students and the relationship between foot health and physical health, providing theoretical basis for improving the foot health and overall health level of college students.[5]

OBJECTS AND METHODS

Object of study

Forty-nine healthy male college students aged from 19 to 24 years (average 20.10 1.30 years) were selected, with a height of 175.61±4.02cm, a weight of 71.53±12.25kg and an average foot length of 26.10±0.85cm. All subjects had no musculoskeletal and motor nerve diseases.

Research technique

The FootscanUSB2 force-measuring plate was laid flat on the floor, and extended runways were laid on both sides of the force-measuring plate. All subjects took off their shoes and socks, and each subject jogged at a speed of 5m and s respectively. Before exercise, record the heart rate of each subject, and then ask the subject to jog barefoot at a constant speed through the force measuring plate, which records the complete stress of one foot of the subject every time. According to the data, the arch condition, the stress balance of each part during walking and the foot health status of students were analyzed. And calculate the average peak force value, peak force value reaching time, impulse, etc. of each area measured twice.[6]

All data analysis was completed by SPSS11.0 statistical software package. The analysis of male college students with normal distribution variables used independent sample t test, and the comparison of left and right foot pressure parameters in the same group used paired t test, and the results were all expressed by $x \pm s$.

Eight-array plantar stress area division rules

A sole foot is composed of 26 bones (including 14 phalanges, 5 metatarsals and 7 tarsals), which work in coordination with the biological structures such as muscles, joints and ligaments to complete the daily activities of human body. Among them, the toes are composed of distal phalanges, middle phalanges and proximal phalanges, and the other four toes have three joints except the big toe. The phalanges are the parts of the plantar with relatively flexible movement characteristics. In standing, walking and other sports behaviors, muscles drive the phalanges to bend to grasp the ground, which can enhance the movement stability.

In this experiment, the plantar was divided into 8 array areas along the sagittal axis. The eight plantar regions have the same width on the sagittal axis. Figure 1 is a schematic diagram of eight-array region division of foot bones and soles:

From toe to heel: phalange area(P), far metatarsal area(FM), middle metatarsal area(MM), posterior metatarsal area(PM), foot-arch area(AA), cuboid bone area(CB), calcaneus area(C), rear-heel area(RH).

RESULT

Distribution of maximum peak pressure in each area of sole

The average maximum dynamic plantar pressure was (206.38 44.59) n for boys, and the maximum dynamic plantar pressure appeared in 10 cases inside the left heel. 7 cases on the medial side of right heel; Lateral left heel in 4 cases; 3 cases of lateral right heel; 1 case of left 1st toe; 3 cases of right first toe; 1 case of left first metatarsal bone; 2 cases

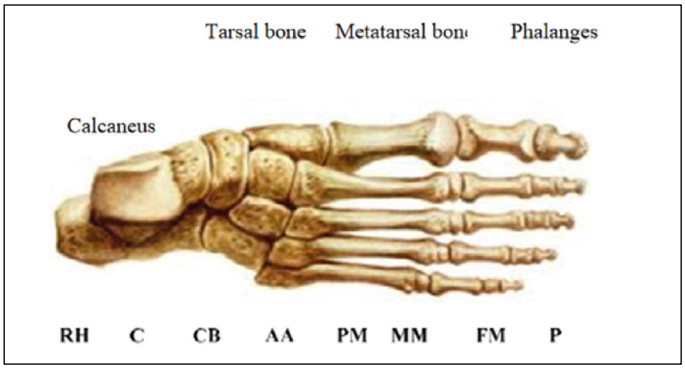

Figure 1. Schematic diagram of eight-array area division of foot bones and soles.

of right first metatarsal bone; 5 cases of left second metatarsal bone; Right second metatarsal in 3 cases; 2 cases of left third metatarsal bone; 2 cases of right third metatarsal bone; 1 case of left fourth metatarsal bone; Right fourth metatarsal in 2 cases; 1 case of right fifth metatarsal bone; Left arch in 2 cases. It can be seen that the maximum plantar pressure during walking is mainly located at the inside of heel and the 2nd and 3rd metatarsal bones. 33% of people feel pain in their heels after walking for a period of time, which is the embodiment of the greatest stress on the inner side of the sole and heel. (Table 1)

Relationship between pressure peak and velocity

Table 2 shows the average peak pressure (AVG) of each plantar region and its percentage to the total pressure when walking at 1.5m/s, and Figure 2 shows the pressure magnitude and change of each plantar region under the slow, medium and fast walking movement in the flat walking movement mode.

It can be seen from the above chart:

1. When walking, the maximum stress areas of plantar occurred in MM, and the minimum stress areas were AA and CB.
2. With the increase of traveling speed, the stress of P, FM, MM, C and RH increases. These areas are concentrated in the forefoot and heel, indicating that when the movement speed increases, the forefoot and heel bear more weight when they provide power and cushion pressure when they touch the ground.
3. With the increase of walking speed, PM stress decreases gradually, indicating that the weight of human body is gradually distributed in the forefoot and heel.

Table 1. Maximum pressure distribution in plantar regions of 49 male college students($x \pm s$, N).

		First toe	The 2 nd to 5 th toes	The first metatarsal bone	The second metatarsal bone	The third metatarsal bone
College boy	Left foot	106.12±56.37	24.61±25.24	88.62±32.08	133.68±50.11	130.01±36.45
	Right foot	122.05±49.86	40.17±33.18	128.96±59.63	155.80±41.37	133.29±30.21
		The fourth metatarsal bone	The fifth metatarsal bone	Arch	Inside heel	Lateral heel
	Left foot	99.62±34.08	79.62±50.11	120.96±64.52	189.63±40.28	167.92±45.03
	Right foot	95.82±33.24	41.28±23.67	66.82±45.02	206.38±44.59	188.28±40.27

Table 2. Average peak plantar pressure and its percentage when walking at 1.5m/s.

Plantar region		P	FM	MM	PM	AA	CB	C	RH
Right foot	Average peak pressure (AVG)	188.25	233.60	266.92	131.24	47.05	40.17	214.65	133.85
	Percentage	14.52%	17.96%	20.33%	11.28%	2.96%	3.74%	18.51%	10.08%
Left foot	Average peak pressure (AVG)	177.93	189.67	250.17	168.52	48.52	4.27	213.72	109.21
	Percentage	14.63%	15.88%	20.15%	17.82%	3.02%	0.88%	18.51%	10.07%

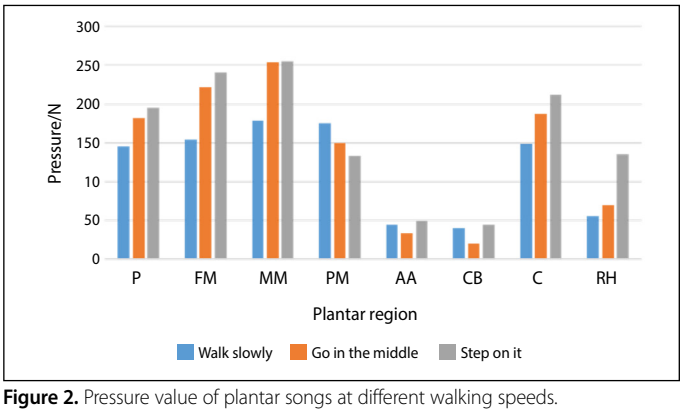

Figure 2. Pressure value of plantar songs at different walking speeds.

4. The walking speed changes of AA and CB in the arch part do not change obviously, at this time, the weight of human body is dispersed to other areas of plantar through arch arch to protect this part from excessive pressure, which indicates that the physiological structure of arch has great protective effect on foot.

Comparison of peak pressure and peak occurrence time in each plantar area before and after fatigue

Table 3 shows that there is no significant difference between the left and right feet ($P > 0.05$) regardless of the peak pressure or the peak time. After fatigue, the peak pressure of FM, AA, RH5 in left foot and FM, AA, CB in right foot decreased significantly ($P < 0.05$, $P < 0.01$). The peak time of RH and CB in left foot was significantly shorter than that before fatigue ($P < 0.05$, $P < 0.01$), while FMF, AA, C areas had no significant change, but tended to be delayed.

Time distribution of peak force value of plantar songs of male college students

From Table 4, it can be seen that there are significant differences between boys' left and right feet except the fifth metatarsal ($P < 0.05$). There is a significant difference in the peak force time between the second and fifth toes of the left foot ($P< 0.01$), and there is a gender difference in the peak force time between the second metatarsal and the third metatarsal ($P < 0.05$).

Table 3. Comparison of peak pressure and peak occurrence time in each plantar area before and after fatigue(n=49).

Zone	Before fatigue		After fatigue	
	Left foot	Right foot	Left foot	Right foot
P	8.23±3.25	8.16±2.11	7.25±2.24	7.06±1.91
FM	4.25±2.01	3.88±1.20	5.21±1.24	4.11±0.27
MM	10.21±4.82	9.09±3.20	8.01±2.50	8.11±2.71
PM	19.24±4.49	19.01±4.01	18.22±3.27	18.77±3.11
AA	20.11±3.01	19.24±2.84	20.05±2.10	19.33±3.17
CB	15.21±2.66	14.74±3.45	15.67±3.38	15.07±2.88
C	13.74±3.24	13.11±3.74	12.09±2.71	12.74
RH	14.27±3.67	14.02±3.62	13.71±2.81	13.74±3.60

Table 4. Time distribution of peak force value of plantar songs of male college students.

Zone	College boy(n=49)	
P	Left foot	Right foot
FM	452.31±58.92	448.62±61.24
MM	552.04±60.17	548.93±47.92
PM	419.26±55.24	405.14±59.63
AA	491.±47±57.81	480.73±44.52
CB	521.79±61.37	517.32±59.02
C	472.62±55.18	466.38±45.24
RH	577.82±59.06	562.38±50.07

DISCUSSION

The research on plantar pressure has been carried out for many years at home and abroad, but different scholars have different test results and research viewpoints on the measurement of plantar pressure. Under normal circumstances, in the whole gait period, the first 15% is the foot-following stage, the first 15% ~ 50% belongs to the foot-supporting stage, and the foot-pushing stage accounts for 50% ~ 100% of the whole gait period. In addition, different areas, different living habits and different experimental instruments may have certain influence on the test results.

After fatigue, the peak pressure in each plantar area is obviously lower than that before fatigue, which may be related to the decrease of muscle strength after fatigue. The decrease of muscle strength leads to

the decrease of the force between foot and ground, which leads to the decrease of peak pressure. Zhao Yihong et al.[11] showed that the average peak force of the plantar pressure inside the heel of normal young people was the largest, followed by the second and third metatarsal bones, and the average peak force of the second to fifth toes and fifth metatarsal bones was smaller. Foreign studies show that the maximum plantar pressure of normal people is located in the first metatarsal bone.[12] The maximum plantar pressure distribution in this experiment is the same as that in Zhang Qinglai's research. The peak force time of each plantar area increases in turn according to the order of plantar contact with the ground during walking, that is, the peak force time is heel < arch < metatarsal < toe, and the change law of left and right feet of men and women is consistent.

Load rate is the load change rate, which indicates how fast the pressure changes and can be interpreted as the load change rate of each anatomical region of the sole. The faster the change, the greater the local pressure stimulation, which can evaluate the shock absorption function of heel, and can also be used to evaluate diabetic foot. The higher the value, the more prone to ulcer. The maximum pressure of the foot is located in the second metatarsal bone. The pressure of the second metatarsal bone, the first metatarsal bone and the first phalanx of the right foot is greater than that of the left foot when jogging, and the difference is significant. This may be due to the fact that most of the subjects' right foot is the dominant foot, and they are more accustomed to using the right foot to support and exert force. For a long time, the transverse arch of the foot can not play its due role, resulting in higher pressure in the forefoot of the right foot. This requires that attention should be paid to reducing the harm of impact force to foot and body, prolonging the contact time between sole and ground, making full use of the cushioning effect of arch and knee joint, and not using too much force to cause unnecessary damage.

CONCLUSION

Male college students have some problems in foot health, and the attention to foot health care is not enough. Through the comparative study of plantar pressure distribution before and after fatigue, it is found that after fatigue, the foot-following stage is obviously shortened and the foot-supporting stage is obviously prolonged; The parameters of plantar pressure also changed correspondingly. The degree of foot varus increased, but individual differences were large.

The author declare no potential conflict of interest related to this article

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REFERENCES

1. Sheng F, Yang P. Fuzzy evaluation of adolescents' health literacy based on early warning theory of psychological risk. Journal of Intelligent & Fuzzy Systems (Preprint): 1-7.
2. Xu X. Study on plantar pressure stability of young people. Journal of Liaoning Police College. 2017;19(1):54-9.
3. Cotoros D, Stanciu A. Composite Insoles for Improving the Distribution of Plantar Pressure. Macromolecular Symposia. 2020;389(1):1900081.
4. Zhao K. Plantar pressure gait analysis of normal and flat feet of college students. Journal of Contemporary Sports. 2019;(19):0004-0006.
5. Chen XM, Liang W. Effect of muscle strength balance correction training on plantar pressure of young male basketball players. Journal of Qufu Normal University: Natural Science Edition. 2019;45(01):112-6.
6. Xu RX, Liu H, Guo MY, Zhao YH, Yan SY, Yang L. Distribution characteristics of plantar pressure in the outer eight gait population. China Leather. 2020;49(763-7):7-12.