

不同高度负跟鞋对健康成人腰腹肌和下肢肌活动的影响

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摘 要 目的:探讨不同高度负跟鞋对健康成人腰腹肌和下肢肌活动的影响。方法:选取 45 名健康成人作为受试者,男 15 名、女 30 名,年龄(34.87 ± 12.79)岁,身高(167.93 ± 7.15)cm,体质量(65.87 ± 10.82)kg。采用 BTS FreeEMG300 无线表面肌电系统测定受试者依次穿 5 种不同高度的负跟鞋(平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋、1.5 cm 负跟鞋、2 cm 负跟鞋)自然匀速直线行走 7 个步行周期时,双侧腹直肌、腰椎旁肌、胫骨前肌及腓肠肌内侧头的表面肌电信号均方根值(root mean square, RMS)。结果:①腹直肌。受试者穿同一高度负跟鞋行走时,双侧腹直肌表面肌电信号 RMS 比较,差异均无统计学意义[平底鞋:(15.80, 13.59) μV , (17.81, 11.70) μV , $Z = -5.150$, $P = 0.606$; 0.5 cm 负跟鞋:(16.58, 11.77) μV , (17.38, 10.77) μV , $Z = -0.125$, $P = 0.901$; 1 cm 负跟鞋:(16.33, 11.62) μV , (17.25, 12.12) μV , $Z = -5.190$, $P = 0.604$; 1.5 cm 负跟鞋:(17.50, 11.51) μV , (18.09, 12.47) μV , $Z = -0.023$, $P = 0.981$; 2 cm 负跟鞋:(16.80, 11.41) μV , (17.64, 10.86) μV , $Z = -0.164$, $P = 0.870$];受试者穿不同高度负跟鞋行走时,同侧腹直肌表面肌电信号 RMS 比较,差异均无统计学意义(左侧: $\chi^2 = 9.191$, $P = 0.056$;右侧: $\chi^2 = 8.645$, $P = 0.071$)。②腰椎旁肌。受试者穿同一高度负跟鞋行走时,双侧腰椎旁肌表面肌电信号 RMS 比较,差异均无统计学意义[平底鞋:(5.43, 5.46) μV , (5.65, 3.45) μV , $Z = -0.412$, $P = 0.681$; 0.5 cm 负跟鞋:(6.04, 5.25) μV , (6.53, 3.54) μV , $Z = -0.198$, $P = 0.843$; 1 cm 负跟鞋:(6.10, 5.60) μV , (6.00, 4.21) μV , $Z = -0.149$, $P = 0.881$; 1.5 cm 负跟鞋:(5.85, 5.82) μV , (5.83, 4.20) μV , $Z = -0.222$, $P = 0.824$; 2 cm 负跟鞋:(6.60, 5.15) μV , (5.73, 4.41) μV , $Z = -0.052$, $P = 0.958$];受试者穿不同高度负跟鞋行走时,同侧腰椎旁肌表面肌电信号 RMS 比较,差异均无统计学意义(左侧: $\chi^2 = 4.996$, $P = 0.288$;右侧: $\chi^2 = 9.156$, $P = 0.057$)。③胫骨前肌。受试者穿同一高度负跟鞋行走时,双侧胫骨前肌表面肌电信号 RMS 比较,差异均无统计学意义[平底鞋:(51.27, 39.27) μV , (49.65, 48.12) μV , $Z = -0.399$, $P = 0.690$; 0.5 cm 负跟鞋:(51.92, 42.07) μV , (54.11, 46.61) μV , $Z = -0.101$, $P = 0.920$; 1 cm 负跟鞋:(51.46, 39.79) μV , (58.69, 33.93) μV , $Z = -0.488$, $P = 0.625$; 1.5 cm 负跟鞋:(58.53, 29.36) μV , (49.16, 47.71) μV , $Z = -0.480$, $P = 0.631$; 2 cm 负跟鞋:(56.26, 41.17) μV , (53.54, 45.56) μV , $Z = -0.246$, $P = 0.806$];受试者穿不同高度负跟鞋行走时,右侧胫骨前肌表面肌电信号 RMS 的差异无统计学意义($\chi^2 = 5.831$, $P = 0.212$)。受试者穿平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋行走时的左侧胫骨前肌表面肌电信号 RMS 均低于穿 2 cm 负跟鞋行走时的左侧胫骨前肌表面肌电信号 RMS ($\chi^2 = -4.133$, $P = 0.000$; $\chi^2 = -2.867$, $P = 0.041$; $\chi^2 = -3.000$, $P = 0.027$)。穿平底鞋行走时的左侧胫骨前肌表面肌电信号 RMS 低于穿 1.5 cm 负跟鞋行走时的左侧胫骨前肌表面肌电信号 RMS ($\chi^2 = -3.133$, $P = 0.017$)。④腓肠肌内侧头。受试者穿同一高度负跟鞋行走时,双侧腓肠肌内侧头表面肌电信号 RMS 比较,差异均无统计学意义[平底鞋:(50.13, 28.83) μV , (51.75, 30.80) μV , $Z = -0.344$, $P = 0.731$; 0.5 cm 负跟鞋:(53.14, 28.77) μV , (56.79, 32.07) μV , $Z = -0.246$, $P = 0.806$; 1 cm 负跟鞋:(53.04, 27.31) μV , (54.46, 26.19) μV , $Z = -0.026$, $P = 0.979$; 1.5 cm 负跟鞋:(56.17, 27.91) μV , (58.90, 31.46) μV , $Z = -0.064$, $P = 0.949$; 2 cm 负跟鞋:(53.36, 34.45) μV , (58.19, 32.32) μV , $Z = -0.563$, $P = 0.573$]。受试者穿不同高度负跟鞋行走时,左侧腓肠肌内侧头表面肌电信号 RMS 两两比较,差异均无统计学意义。受试者穿平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋行走时的右侧腓肠肌内侧头表面肌电信号 RMS 均低于穿 2 cm 负跟鞋行走时的右侧腓肠肌内侧头表面肌电信号 RMS ($\chi^2 = -3.333$, $P = 0.009$; $\chi^2 = -3.000$, $P = 0.027$; $\chi^2 = -3.467$, $P = 0.005$)。结论:健康成人穿高度 ≤ 2 cm 的负跟鞋短时间匀速直线行走,不会影响两侧腰腹肌和下肢肌收缩的对称性;负跟鞋高度对下肢肌活动影响较大,对腰腹肌无明显影响。

关键词 肌电描记术;负跟鞋;腰肌;腹肌;下肢肌;横断面研究

Effects of negative heel shoes of different heights on the activity of psoas and abdominal muscles and lower limb muscles in healthy adults

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基金项目:二〇二一年度新乡医学院第一附属医院青年培育基金项目(QN-2021-B04)

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ABSTRACT Objective: To investigate the effects of negative heel shoes of different heights on the activity of psoas and abdominal muscles and lower limb muscles in healthy adults. **Methods:** Forty-five healthy adults were enrolled, including 15 males and 30 females, with age of (34.87 ± 12.79) years, height of (167.93 ± 7.15) cm, and weight of (65.87 ± 10.82) kg. The surface electromyography (EMG) signals of the bilateral rectus abdominis, paravertebral muscle, tibialis anterior, and medial head of the gastrocnemius muscle were measured using the BTS FreeEMG300 wireless surface EMG system while the participants walked in a straight line at a natural and uniform pace for seven walking cycles in five different heights of negative heel shoes (flat shoes, 0.5 cm, 1 cm, 1.5 cm, and 2 cm negative heel shoes). The root mean square (RMS) of the surface EMG signals was calculated. **Results:** ① Rectus abdominis. When the participants walked in negative heel shoes of the same height, there was no statistical difference in the RMS of the surface EMG signals between the bilateral rectus abdominis (flat shoes: $(15.80, 13.59)$ vs $(17.81, 11.70)$ μV , $Z = -5.150$, $P = 0.606$; 0.5 cm negative heel shoes: $(16.58, 11.77)$ vs $(17.38, 10.77)$ μV , $Z = -0.125$, $P = 0.901$; 1 cm negative heel shoes: $(16.33, 11.62)$ vs $(17.25, 12.12)$ μV , $Z = -5.190$, $P = 0.604$; 1.5 cm negative heel shoes: $(17.50, 11.51)$ vs $(18.09, 12.47)$ μV , $Z = -0.023$, $P = 0.981$; 2 cm negative heel shoes: $(16.80, 11.41)$ vs $(17.64, 10.86)$ μV , $Z = -0.164$, $P = 0.870$). When the participants walked in negative heel shoes of different heights, there was no statistical difference in the RMS of the surface EMG signals of the ipsilateral rectus abdominis (left side: $\chi^2 = 9.191$, $P = 0.056$; right side: $\chi^2 = 8.645$, $P = 0.071$). ② Paravertebral muscle. When the participants walked in negative heel shoes of the same height, there was no statistical difference in the RMS of surface EMG signals between the bilateral paravertebral muscle (flat shoes: $(5.43, 5.46)$ vs $(5.65, 3.45)$ μV , $Z = -0.412$, $P = 0.681$; 0.5 cm negative heel shoes: $(6.04, 5.25)$ vs $(6.53, 3.54)$ μV , $Z = -0.198$, $P = 0.843$; 1 cm negative heel shoes: $(6.10, 5.60)$ vs $(6.00, 4.21)$ μV , $Z = -0.149$, $P = 0.881$; 1.5 cm negative heel shoes: $(5.85, 5.82)$ vs $(5.83, 4.20)$ μV , $Z = -0.222$, $P = 0.824$; 2 cm negative heel shoes: $(6.60, 5.15)$ vs $(5.73, 4.41)$ μV , $Z = -0.052$, $P = 0.958$). When the participants walked in negative heel shoes of different heights, there was no statistical difference in the RMS of surface EMG signals of the ipsilateral paravertebral muscle (left side: $\chi^2 = 4.996$, $P = 0.288$; right side: $\chi^2 = 9.156$, $P = 0.057$). ③ Tibialis anterior. When the participants walked in negative heel shoes of the same height, there was no statistical difference in the RMS of surface EMG signals between the bilateral tibialis anterior (flat shoes: $(51.27, 39.27)$ vs $(49.65, 48.12)$ μV , $Z = -0.399$, $P = 0.690$; 0.5 cm negative heel shoes: $(51.92, 42.07)$ vs $(54.11, 46.61)$ μV , $Z = -0.101$, $P = 0.920$; 1 cm negative heel shoes: $(51.46, 39.79)$ vs $(58.69, 33.93)$ μV , $Z = -0.488$, $P = 0.625$; 1.5 cm negative heel shoes: $(58.53, 29.36)$ vs $(49.16, 47.71)$ μV , $Z = -0.480$, $P = 0.631$; 2 cm negative heel shoes: $(56.26, 41.17)$ vs $(53.54, 45.56)$ μV , $Z = -0.246$, $P = 0.806$). When the participants walked in negative heel shoes of different heights, there was no statistical difference in the RMS of surface EMG signals of the tibialis anterior on the right side ($\chi^2 = 5.831$, $P = 0.212$). The RMS of the surface EMG signals of the tibialis anterior on the left side when participants walked in flat shoes, 0.5 cm negative heel shoes, and 1 cm negative heel shoes was lower than that in 2 cm negative heel shoes ($\chi^2 = -4.133$, $P = 0.000$; $\chi^2 = -2.867$, $P = 0.041$; $\chi^2 = -3.000$, $P = 0.027$). The RMS of the surface EMG signals of the tibialis anterior on the left side when participants walked in flat shoes was lower than that in 1.5 cm negative heel shoes ($\chi^2 = -3.133$, $P = 0.017$). ④ Medial head of the gastrocnemius muscle. When the participants walked in negative heel shoes of the same height, there was no statistical difference in the RMS of surface EMG signals between the bilateral medial head of the gastrocnemius muscle (flat shoes: $(50.13, 28.83)$ vs $(51.75, 30.80)$ μV , $Z = -0.344$, $P = 0.731$; 0.5 cm negative heel shoes: $(53.14, 28.77)$ vs $(56.79, 32.07)$ μV , $Z = -0.246$, $P = 0.806$; 1 cm negative heel shoes: $(53.04, 27.31)$ vs $(54.46, 26.19)$ μV , $Z = -0.026$, $P = 0.979$; 1.5 cm negative heel shoes: $(56.17, 27.91)$ vs $(58.90, 31.46)$ μV , $Z = -0.064$, $P = 0.949$; 2 cm negative heel shoes: $(53.36, 34.45)$ vs $(58.19, 32.32)$ μV , $Z = -0.563$, $P = 0.573$). When the participants walked in negative heel shoes of different heights, there was no statistical difference in the RMS of the surface EMG signals of the medial head of the gastrocnemius muscle on the left side. The RMS of the surface EMG signals of the medial head of the gastrocnemius muscle on the right side when participants walked in flat shoes, 0.5 cm negative heel shoes, and 1 cm negative heel shoes was lower than that in 2 cm negative heel shoes ($\chi^2 = -3.333$, $P = 0.009$; $\chi^2 = -3.000$, $P = 0.027$; $\chi^2 = -3.467$, $P = 0.005$). **Conclusion:** For healthy adults, walking in a straight line at a constant speed in negative heel shoes with a height of ≤ 2 cm does not affect the symmetry of the contraction of the bilateral psoas muscles, abdominal muscles, and muscle of lower limb. The height of the negative heel shoes has a significant impact on the activity of the muscle of lower limb but has no significant effect on the psoas and abdominal muscles.

Keywords electromyography; negative heel shoes; psoas muscles; abdominal muscles; muscle of lower limb; cross-sectional studies

负跟鞋是一种鞋底前端高于鞋跟的鞋,穿负跟鞋对腰腿疼痛有一定康复作用^[1-2],但目前仍缺乏相关作用机制的研究。表面肌电图是通过在皮肤表面放置电极,记录邻近神经肌肉系统活动时的生物电信号的测定方法,与肌肉的活动状态和功能状态之间存在着不同程度的关联性,能在一定程度上反映神经肌肉的活动^[3-4]。本研究探讨了不同高度负跟鞋对健康成人腰腹肌和下肢肌活动的影响,现总结报告如下。

1 临床资料

1.1 研究对象 2022 年 2—4 月,选择新乡医学院第一附属医院康复科的治疗师和实习生进行研究。试验方案经新乡医学院第一附属医院医学伦理委员会审查通过,伦理批件号:2021034。

1.2 纳入标准 ①年龄 18~35 岁;②身高 160~180 cm;③ $18 \text{ kg} \cdot \text{m}^{-2} \leq \text{体质量指数} \leq 25 \text{ kg} \cdot \text{m}^{-2}$;④女性鞋码 36~39 码,男性鞋码 38~42 码;⑤优势侧为右侧;⑥同意参与本研究,签署知情同意书。

1.3 排除标准 ①骨盆不对称和(或)双下肢不等长者;②既往曾应用负跟鞋治疗者;③有下肢或脊柱手术史者。

2 方法

2.1 负跟鞋制作 试验用负跟鞋由普通平底布鞋改造而成。用轻质鞋垫材料将平底鞋鞋底前 1/3~1/2 加厚,改造后的鞋底呈平缓的前高后低形态。女性试验鞋鞋码为 36~39 码,男性试验鞋鞋码为 38~42 码。每个鞋码均制备 5 种高度的负跟鞋,即平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋、1.5 cm 负跟鞋、2 cm 负跟鞋(图 1)。

2.2 腰腹肌和下肢肌表面肌电信号测定 所有受试

者试验前 1 天禁止剧烈体育运动。试验在室内进行,温度 22~28 ℃。所用设备包括 BTS FreeEMG300 无线表面肌电系统,一次性心电电极片(杭州迅达无线电器材有限公司),LifeFitness 跑步机。先用磨砂纸摩擦皮肤去除死皮,毛发较多时须剔除相应区域毛发,再用酒精擦拭,待皮肤干燥后再放置电极片。在直立位下沿肌腹长轴放置一次性心电电极片,双侧同一肌群电极片放置位置须对称。腹直肌电极片位置为脐旁 3 cm,腰椎旁肌电极片位置为 L₃₋₄ 水平、后正中线外侧肌腹隆起处,胫骨前肌电极片位置为胫骨外侧胫骨前肌肌腹隆起最高点,腓肠肌内侧头电极片位置为其肌腹隆起处。电极片通过蓝牙与计算机连接。

测试前,受试者试穿 5 种鞋分别在跑步机上行走 2 min(设定跑步机速度为 $2 \text{ km} \cdot \text{h}^{-1}$)以适应试验用鞋。测试时,受试者依次穿平底鞋、0.5 cm 负跟鞋、1.0 cm 负跟鞋、1.5 cm 负跟鞋、2.0 cm 负跟鞋,测试方法和流程相同。受试者穿对应的负跟鞋按照日常行走状态在跑步机上自然匀速直线行走,记录 7 个步行周期后休息 1 min,重复测量 3 次。在生成的分析报告中,截取行走的 7 个步行周期中所测试肌群中间收缩 3 次的表面肌电信号^[3],取 3 次测量的表面肌电信号均方根值(root mean square, RMS)的平均值。

2.3 数据统计 采用 SPSS25.0 软件进行数据分析。受试者穿同一高度负跟鞋行走时,双侧同一肌群表面肌电信号 RMS 比较均采用 Mann-Whitney U 检验;受试者穿不同高度负跟鞋行走时,同侧同一肌群表面肌电信号 RMS 的比较和进一步两两比较均采用 Friedman 检验,并采用 Bonferroni 法矫正。检验水准 $\alpha = 0.05$ 。



图 1 试验用负跟鞋外观图

3 结 果

3.1 一般情况 共纳入 45 名受试者,男 15 名、女 30 名,年龄 (24.87 ± 5.29) 岁,身高 (167.93 ± 7.15) cm,体质量 (65.87 ± 10.82) kg。

3.2 腰腹肌和下肢肌表面肌电信号测定结果

3.2.1 腹直肌 受试者穿同一高度负跟鞋行走时,双侧腹直肌表面肌电信号 RMS 比较,差异均无统计学意义;受试者穿不同高度负跟鞋行走时,同侧腹直肌表面肌电信号 RMS 比较,差异均无统计学意义(表 1)。

3.2.2 腰椎旁肌 受试者穿同一高度负跟鞋行走时,双侧腰椎旁肌表面肌电信号 RMS 比较,差异均无统计学意义;受试者穿不同高度负跟鞋行走时,同侧腰椎旁肌表面肌电信号 RMS 比较,差异均无统计学意义(表 2)。

3.2.3 胫骨前肌 受试者穿同一高度负跟鞋行走时,双侧胫骨前肌表面肌电信号 RMS 比较,差异均无统计学意义。受试者穿不同高度负跟鞋行走时,右侧胫骨前肌表面肌电信号 RMS 的差异无统计学意义。受试者穿不同高度负跟鞋行走时,左侧胫骨前肌表面肌电信号 RMS 的差异有统计学意义;进一步两两比较,受试者穿平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋行

走时的胫骨前肌表面肌电信号 RMS 均低于穿 2 cm 负跟鞋行走时的胫骨前肌表面肌电信号 RMS ($\chi^2 = -4.133, P = 0.000$; $\chi^2 = -2.867, P = 0.041$; $\chi^2 = -3.000, P = 0.027$),穿平底鞋行走时的胫骨前肌表面肌电信号 RMS 低于穿 1.5 cm 负跟鞋行走时的胫骨前肌表面肌电信号 RMS ($\chi^2 = -3.133, P = 0.017$),其余两两比较的差异均无统计学意义。见表 3。

3.2.4 腓肠肌内侧头 受试者穿同一高度负跟鞋行走时,双侧腓肠肌内侧头表面肌电信号 RMS 比较,差异均无统计学意义。受试者穿不同高度负跟鞋行走时,左侧腓肠肌内侧头表面肌电信号 RMS 的差异有统计学意义;进一步两两比较,差异均无统计学意义。受试者穿不同高度负跟鞋行走时,右侧腓肠肌内侧头表面肌电信号 RMS 的差异有统计学意义;进一步两两比较,受试者穿平底鞋、0.5 cm 负跟鞋、1 cm 负跟鞋行走时的表面肌电信号 RMS 均低于穿 2 cm 负跟鞋行走时的表面肌电信号 RMS ($\chi^2 = -3.333, P = 0.009$; $\chi^2 = -3.000, P = 0.027$; $\chi^2 = -3.467, P = 0.005$),其余两两比较的差异均无统计学意义。见表 4。

表 1 受试者穿 5 种负跟鞋行走时的腹直肌表面肌电信号均方根值

测试肌群	样本量/ 名	表面肌电信号均方根值/[$(M, Q), \mu V$]					χ^2 值	P 值
		平底鞋	0.5 cm 负跟鞋	1 cm 负跟鞋	1.5 cm 负跟鞋	2 cm 负跟鞋		
左侧腹直肌	45	15.80, 13.59	16.58, 11.77	16.33, 11.62	17.50, 11.51	16.80, 11.41	9.191	0.056
右侧腹直肌	45	17.81, 11.70	17.38, 10.77	17.25, 12.12	18.09, 12.47	17.64, 10.86	8.645	0.071
Z 值		-5.150	-0.125	-5.190	-0.023	-0.164		
P 值		0.606	0.901	0.604	0.981	0.870		

表 2 受试者穿 5 种负跟鞋行走时的腰椎旁肌表面肌电信号均方根值

测试肌群	样本量/ 名	表面肌电信号均方根值/[$(M, Q), \mu V$]					χ^2 值	P 值
		平底鞋	0.5 cm 负跟鞋	1 cm 负跟鞋	1.5 cm 负跟鞋	2 cm 负跟鞋		
左侧腰椎旁肌	45	5.43, 5.46	6.04, 5.25	6.10, 5.60	5.85, 5.82	6.60, 5.15	4.996	0.288
右侧腰椎旁肌	45	5.65, 3.45	6.53, 3.54	6.00, 4.21	5.83, 4.20	5.73, 4.41	9.156	0.057
Z 值		-0.412	-0.198	-0.149	-0.222	-0.052		
P 值		0.681	0.843	0.881	0.824	0.958		

表 3 受试者穿 5 种负跟鞋行走时的胫骨前肌表面肌电信号均方根值

测试肌群	样本量/ 名	表面肌电信号均方根值/[$(M, Q), \mu V$]					χ^2 值	P 值
		平底鞋	0.5 cm 负跟鞋	1 cm 负跟鞋	1.5 cm 负跟鞋	2 cm 负跟鞋		
左侧胫骨前肌	45	51.27, 39.27	51.92, 42.07	51.46, 39.79	58.53, 29.36	56.26, 41.17	22.204	0.000
右侧胫骨前肌	45	49.65, 48.12	54.11, 46.61	58.69, 33.93	49.16, 47.71	53.54, 45.56	5.831	0.212
Z 值		-0.399	-0.101	-0.488	-0.480	-0.246		
P 值		0.690	0.920	0.625	0.631	0.806		

表 4 受试者穿 5 种负跟鞋行走时的腓肠肌内侧头表面肌电信号均方根值

测试肌群	样本量/ 名	表面肌电信号均方根值/[(M,Q), μV]					χ^2 值	P 值
		平底鞋	0.5 cm 负跟鞋	1 cm 负跟鞋	1.5 cm 负跟鞋	2 cm 负跟鞋		
左侧腓肠肌内侧头	45	50.13, 28.83	53.14, 28.77	53.04, 27.31	56.17, 27.91	53.36, 34.45	9.724	0.045
右侧腓肠肌内侧头	45	51.75, 30.80	56.79, 32.07	54.46, 26.19	58.90, 31.46	58.19, 32.32	16.338	0.003
Z 值		-0.344	-0.246	-0.026	-0.064	-0.563		
P 值		0.731	0.806	0.979	0.949	0.573		

4 讨 论

鞋跟高度会影响维持人体行走平衡的肌群,行走不平衡时,人体可通过髌、膝、踝关节旋转代偿来维持平衡,会引起下肢肌群肌电参数的变化^[5]。表面肌电图是一种评估神经肌肉功能的方法,在康复医学领域应用广泛^[6],常用的分析方法为时域分析和频域分析。RMS 是时域分析的常用指标,可以用来评估肌力。

本研究中受试者穿不同高度负跟鞋行走时,两侧腹直肌、腰椎旁肌、胫骨前肌、腓肠肌内侧头表面肌电信号 RMS 均无明显差异。这表明短时间匀速直线行走时,健康成人穿高度 ≤ 2 cm 的负跟鞋不会影响两侧腰腹肌和下肢肌收缩的对称性。已有研究表明,腰痛患者两侧椎旁肌收缩不对称,单侧疼痛的腰椎间盘突出症患者腰腹肌表面肌电信号 RMS 低于健康者^[7-8],腰痛患者患侧椎旁肌的肌力小于健侧^[9]。腰腹肌收缩时,左右两侧存在差异会增加其损伤的风险;腹部肌群与腰椎旁肌共同收缩有助于维持骨盆和腰椎的稳定^[10-12]。

Bai 等^[13]研究发现,穿中间高、前后低的鞋行走,会刺激人体躯干肌收缩,使腹直肌、竖脊肌表面肌电信号增强。本研究中未发现穿负跟鞋会增强腹直肌和腰椎旁肌的表面肌电信号,即穿负跟鞋无法增强腰腹肌群的肌肉收缩,无法增强核心肌群肌力。这与朱瑶佳等^[14]的研究结论相似。其原因可能包括两个方面:一方面可能与骨盆代偿有关。穿负跟鞋时踝关节背伸增加,髌关节和膝关节通过增加屈曲角度进行代偿,使负跟鞋对躯干肌的影响小于下肢肌。人体稳定性的维持还需要本体感觉的参与,静态站立时踝关节本体感觉对姿势控制贡献最大,而行走时髌关节本体感觉对姿势控制的贡献较大^[15-16]。另一方面可能与本试验中受试者行走速度慢、行走时间短有关。已有研究表明,行走过程中步行速度对步态参数有较大的影响,肌肉疲劳会改变步态运动学和肌肉肌电活动特征^[17-18];加快跑步速度会使下肢肌表面肌电信号产生较大变化^[19]。

朱瑶佳等^[14]的研究发现,人体重心向后移动时胫骨前肌、腓肠肌内侧头被明显激活。这与本研究的结果一致。腓肠肌与胫骨前肌为行走时踝关节背伸和跖屈过程中的一对拮抗肌,拮抗肌共活化可以维持关节稳定,共同收缩提高关节稳定性^[20]。研究表明,优势腿比非优势腿本体感觉差,但二者稳定性无明显差异^[21]。王静等^[22]基于表面肌电的步态分析表明,健康人自然步行时,优势侧下肢肌表面肌电信号的时域和频域参数值在一定时间内均大于非优势侧。这与以往认为健康人活动时,左右两侧同一类型肌群表面肌电信号无明显差异的观点不同^[23]。本研究的受试者均为右侧优势,受试者穿不同高度负跟鞋行走时,腹直肌、腰椎旁肌、胫骨前肌、腓肠肌内侧头均未表现出明显的右侧优势,左侧胫骨前肌和右侧腓肠肌内侧头肌肉活动变化较大。一方面可能与本研究设计的负跟鞋有关。人足跟骨为圆形,行走时容易外偏。本研究中使用的负跟鞋仅在鞋底前后方向上存在高度变化,未对鞋底进行内倾设计,无法维持行走期间足部的内-外侧稳定性,可能会干扰两侧胫骨前肌正常募集。另一方面可能与本研究样本量小及数据采集过程中的各种误差有关。

本研究结果表明,健康成人穿高度 ≤ 2 cm 的负跟鞋短时间匀速直线行走,不会影响两侧腰腹肌和下肢肌收缩的对称性;负跟鞋高度对下肢肌活动影响较大,对腰腹肌无明显影响。

参考文献

- [1] 樊一婷. 负跟鞋对人体运动时髌、膝、踝的生物力学影响分析[J]. 中国皮革, 2022, 51(5): 75-78.
- [2] 翟佳滨, 任连军, 王祁荣. 负跟鞋足部“穴位”按摩保健的医学实验与临床观察[J]. 双足与保健, 2019(2): 39-40.
- [3] PAPAGIANNIS G I, TRIANTAFYLLOU A I, ROUMPELAKIS I M, et al. Methodology of surface electromyography in gait analysis: review of the literature[J]. J Med Eng Technol, 2019, 43(1): 59-65.
- [4] 李建华, 王建. 表面肌电图诊断技术临床应用[M]. 杭

- 州:浙江大学出版社,2015:177-178.
- [5] 雷烨,田苗,李俊.鞋履对人体平衡稳定性的影响研究进展[J].皮革科学与工程,2020,30(2):30-37.
- [6] 刘凡,曹蕾.表面肌电应用的新进展[J].体育世界(学术版),2019,793(7):149-151.
- [7] HAO Z, XIE L, WANG J, et al. Spatial distribution and asymmetry of surface electromyography on lumbar muscles of soldiers with chronic low back pain[J]. Pain Res Manag, 2020,2020:6946294.
- [8] 陈文敏,肖玲玲,李慧慧,等.单侧痛腰椎间盘突出症的表面肌电信号特征[J].中国医学物理学杂志,2017,34(10):1022-1026.
- [9] 梁杰,陈述荣,卢惠苹,等.单侧腰椎间盘突出症患者椎旁肌表面肌电信号特征[J].按摩与康复医学,2019,10(23):5-7.
- [10] HLAING S S, PUNTUMETAKUL R, KHINE E E, et al. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial[J]. BMC Musculoskelet Disord, 2021,22(1):998.
- [11] KAWAMA R, IKE A, SOMA A, et al. Side-to-side difference in electromyographic activity of abdominal muscles during asymmetric exercises[J]. J Sports Sci Med, 2022,21(4):493-503.
- [12] 赵苛宇,包天链,杨物鹏,等.退行性腰椎管狭窄症与脊柱-骨盆矢状位失衡及椎旁肌退变关系的研究进展[J].中医正骨,2022,34(1):59-62.
- [13] BAI D Y, YUAN Z G, SHAO J J, et al. Unstable shoes for the treatment of lower back pain: a meta-analysis of randomized controlled trials[J]. Clin Rehabil, 2019,33(11):1713-1721.
- [14] 朱瑶佳,霍洪峰.不同姿势站立时人体的平衡能力及足型特征[J].中国组织工程研究,2019,23(15):2345-2349.
- [15] QU X, HU X, ZHAO J, et al. The roles of lower-limb joint proprioception in postural control during gait[J]. Appl Ergon, 2022,99:103635.
- [16] CHEN X, QU X. Age-related differences in the relationships between lower-limb joint proprioception and postural balance[J]. Hum Factors, 2019,61(5):702-711.
- [17] FUKUCHI C A, FUKUCHI R K, DUARTE M. Effects of walking speed on gait biomechanics in healthy participants: a systematic review and meta-analysis[J]. Syst Rev, 2019,8(1):153.
- [18] ZHANG L, YAN Y, LIU G, et al. Effect of fatigue on kinematics, kinetics and muscle activities of lower limbs during gait[J]. Proc Inst Mech Eng H, 2022,236(9):1365-1374.
- [19] WHITELEY R, HANSEN C, THOMSON A, et al. Lower limb EMG activation during reduced gravity running on an incline. Speed matters more than hills irrespective of indicated bodyweight[J]. Gait Posture, 2021,83:52-59.
- [20] LATASH M L. Muscle coactivation: definitions, mechanisms, and functions[J]. J Neurophysiol, 2018,120(1):88-104.
- [21] 陈泽华,叶翔凌,陈伟健,等.健康成年人下肢本体感觉与姿势稳定性的关系[J].中国组织工程研究,2020,24(29):4692-4696.
- [22] 王静,吴效明.基于表面肌电的步态分析[J].中国组织工程研究,2012,16(26):4834-4840.
- [23] HU Y, SIU S H, MAK J N, et al. Lumbar muscle electromyographic dynamic topography during flexion-extension[J]. J Electromyogr Kinesiol, 2010,20(2):246-255.

(收稿日期:2022-10-19 本文编辑:李晓乐)